METHODS AND COSTS OF DRIVING DRIFTS, CROSSCUTS AND RAISES IN THE COEUR D'ALENE MINING DISTRICT, SHOSHONE COUNTY, IDAHO

By George T. Krempasky

* * * * * * * * * * * * information circular 7964

UNITED STATES DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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METHODS AND COSTS OF DRIVING DRIFTS, CROSSCUTS, AND RAISES IN THE COEUR D'ALENE MINING DISTRICT, SHOSHONE COUNTY, IDAHO[1/]

by

George T. Krempasky[2/]

SUMMARY AND INTRODUCTION

This report is one of a series of Bureau of Mines Information Circulars dealing with mining methods and costs throughout the United States. It describes drifting, crosscutting, and raising operations at several mines in the Coeur d'Alene mining district, Shoshone County, Idaho.

Ore bodies in the Coeur d'Alene district are generally in steeply dipping tabular ore zones, are irregular in shape, erratic in occurrence, and have been extensively mined along the strike and down dip. Because of the extended attitude of the deposits a great deal of development work is required. Drifting, crosscutting, and raising methods are described in this report. Shaft sinking is the subject of another report in the same series.

Headings in the Coeur d'Alene district range in size from 6 by 8 feet for small service entries to 10 by 12 feet for main haulageways. Advance per round varies from 5 feet in timbered headings to 8 feet in untimbered headings. Advance per man-shift is from 1.1 to 4.0 linear feet, and averages 28.5 cubic feet. Costs per cubic foot averaged $0.279 for labor, supervision, and engineering; $0.215 for materials and supplies; and $0.012 for miscellaneous, for a total of $0.506 per cubic foot removed. Costs for raising averaged $0.362 for labor; materials and supplies $0.342; and $0.036 for miscellaneous, for a total of $0.74 per cubic foot removed.

The mines are fully mechanized. Automatic drills are mounted on jumbos or airlegs, shoveling is accomplished with overshot loaders or slushers, and air-, diesel-, or battery-operated locomotives are used for transportation and service.

Information and data reporting activity in nine drifts, four crosscuts, and three raises at eight mines are included in this report. Remarks for each heading are made to supplement the information presented in the general section and in the tables.

1/ Work on manuscript completed July 1959.

2/ Mining engineer, Bureau of Mines, Region I, Spokane, Wash.

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LOCATION AND PHYSICAL FEATURES

The Coeur d'Alene mining district is in Shoshone County in the mountainous portion of northern Idaho. The district comprises an area of about 400 square miles extending westward from the Montana-Idaho border to the town of Pinehurst and from Burke south to Wallace (fig. 1). Wallace is the county seat of Shoshone County and the principal town of the district. The population center of northern Idaho is the Kellogg-Wallace area. The area is crossed by U.S. Highway No. 10 from east to west and by branch lines of the Union Pacific and Northern Pacific Railroads. Hydroelectric power is distributed throughout the district by the Washington Water Power Co. and by the Montana Power Co. through 110,000-volt transmission lines. The voltage is stepped down to 13,000 and 16,500 volts for distribution to the mines.

Topographically the district is mountainous, but the land forms are rounded. Altitudes range from 2,200 feet in the Coeur d'Alene River valley to 6,295 feet in the higher mountains. Steep hillsides are covered with a thick soil mantle and are well forested. Owing to deep-seated emplacement of the ore, there are no recognized topographic expressions of the mineralized zones.

HISTORY

The region was first settled in 1842 by Jesuit missionaries. Mining was begun in 1878 with the discovery of placer gold on Elk Creek and later in other stream channels. In 1884 and 1885 lode deposits of lead and silver were discovered, and several well-known mines, including the Morning, Bunker Hill, and Sullivan, were located (1).[3] After the initial discoveries, the region was thoroughly prospected and additional discoveries were made. By 1900 most of the productive surface lodes had been located, and consolidation of the numerous holdings was well underway. Rail access to the district was made available in 1890 with the completion of a spur line of the Northern Pacific Railroad from Missoula, Mont.

Except for economic changes due to labor troubles in 1890 and 1895, and periodic fluctuations in the demand for lead and zinc, the district has enjoyed routine existence. Those mines having high-silver-content ores weathered these periods without difficulty.

3/ Underlined items in parentheses refer to items in the bibliography at the end of this report.

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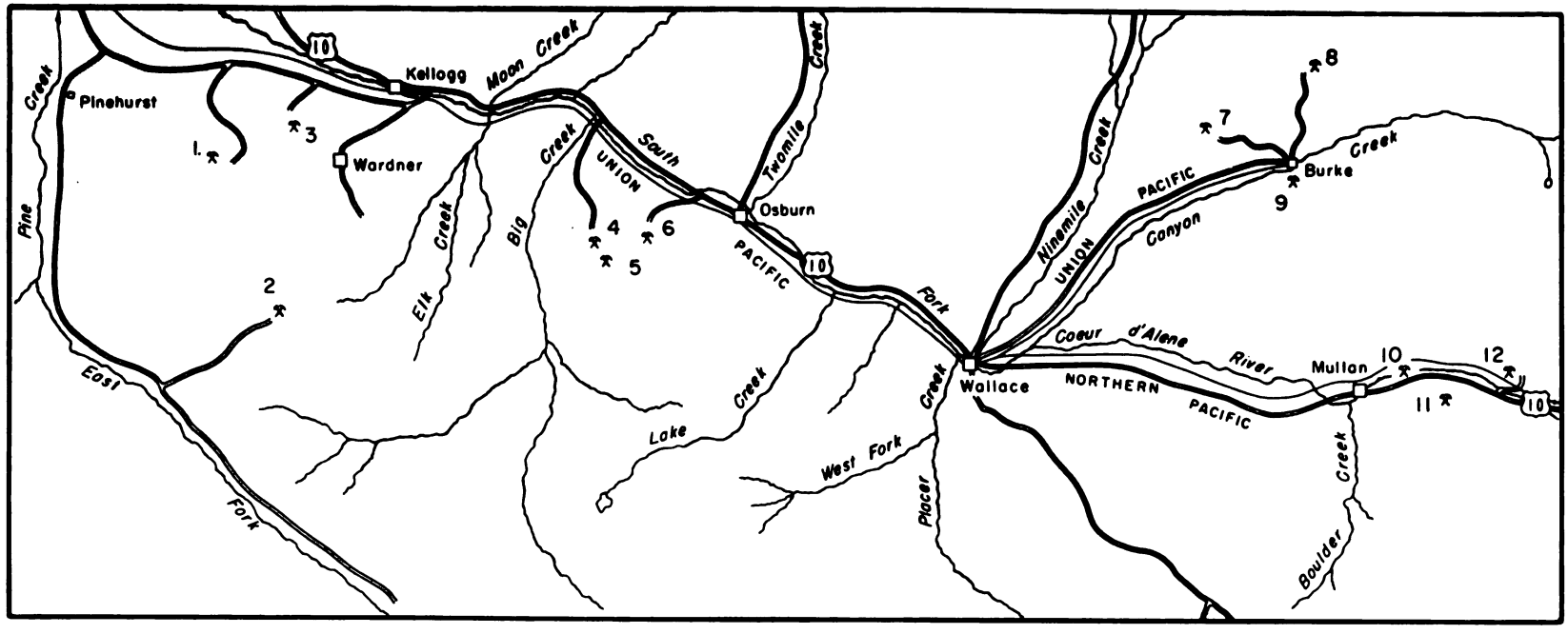
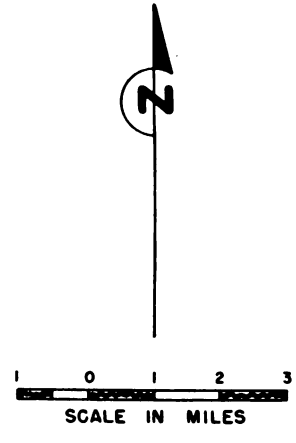


MINES

1. Page
2. Sidney
3. Bunker
4. Crescent
5. Sunshine
6. Polaris
7. Tamarack
8. Hercules
9. Star
10. Lucky Friday
11. Atlas
12. Silver Mountain



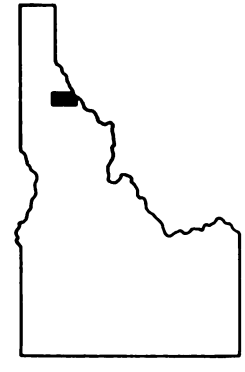


FIGURE 1. - Coeur d'Alene Mining District, Shoshone County, Idaho.

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Although the district is best known as a lead-zinc-silver producer, it is also a ranking copper producer. Copper minerals were recognized in the lead-silver deposits as early as 1884, but it was not until 1904 that a copper concentrate was recovered. Copper occurs mainly in silver-rich tetrahedrite concentrates. The copper minerals found in the district are covellite, chalcocite, and bornite.

The Coeur d'Alene mining district is one of the few districts in the world that has produced over $1 billion in mineral wealth. A total of 420,657 ounces of gold, 572,295,521 ounces of silver, 88,532 short tons of copper, 6,316,326 short tons of lead, and 1,945,172 short tons of zinc was produced from 1884 to 1957. Total value of the recovered metals was $1,703,195,505 (2). The district ranks 1st in silver production in the United States, 2d in lead production, 4th in zinc production, 21st in copper production.

GEOLOGY

The geology of the Coeur d'Alene mining district has been described by Ransome and Calkins (3) and by Umpleby and Jones (4). Rocks of the Coeur d'Alene district may be divided into three groups: Precambrian sediments of the Belt series, igneous rocks intruding the Precambrian series, and recent unconsolidated deposits of alluvium (fig. 2). The Belt series are the most important rocks in areal distribution and economic importance; every important mineral deposit in the district occurs in these metasediments. The Belt series is divided into six formations: Prichard, Burke, Revett, St. Regis, Wallace, and Striped Peak—named in order to decreasing age. The series represents more than 20,000 feet of shallow-water sediments metamorphosed to argillite, slate, and quartzite, in addition to many intermediate types.

Substantial bodies of zinc and zinc-lead ores have been found in the Prichard formation. Ores of lead and lead-zinc are chiefly found in the Burke, Revett, and St. Regis strata. The St. Regis formation also contains silver-bearing tetrahedrite and lead-silver ores.

Igneous rocks of the district are all intrusive and are classed as monzonites, diabase, and lamprophyres. Lamprophyre and diabase are dark fine-grained rocks occurring only in inconspicuous dikes. The monzonites are far more widespread in occurrence and are of more significance, as they are thought to be the source of mineralization of some of the deposits. Significant ore deposits are not found in the igneous rocks. Tertiary and Quaternary alluvium occurs in valley fill and on high benches.

Rocks of the district have been deformed by folding and faulting. Folds are usually unsymmetrical and frequently complex. The principal structural feature of the entire district is the east-west Osburn fault. It has been traced from Coeur d'Alene Lake on the west almost to Missoula, Mont. on the east, a distance of 150 miles. It is a steeply dipping normal fault. Geologic evidence indicates relative horizontal movement of about 12 to 15 miles. Usually several hundred feet of broken rock and gouge represents the fault zone, expressed topographically by a series of saddles in the ridges. Numerous secondary faults are also found in the district. Ore deposits are generally

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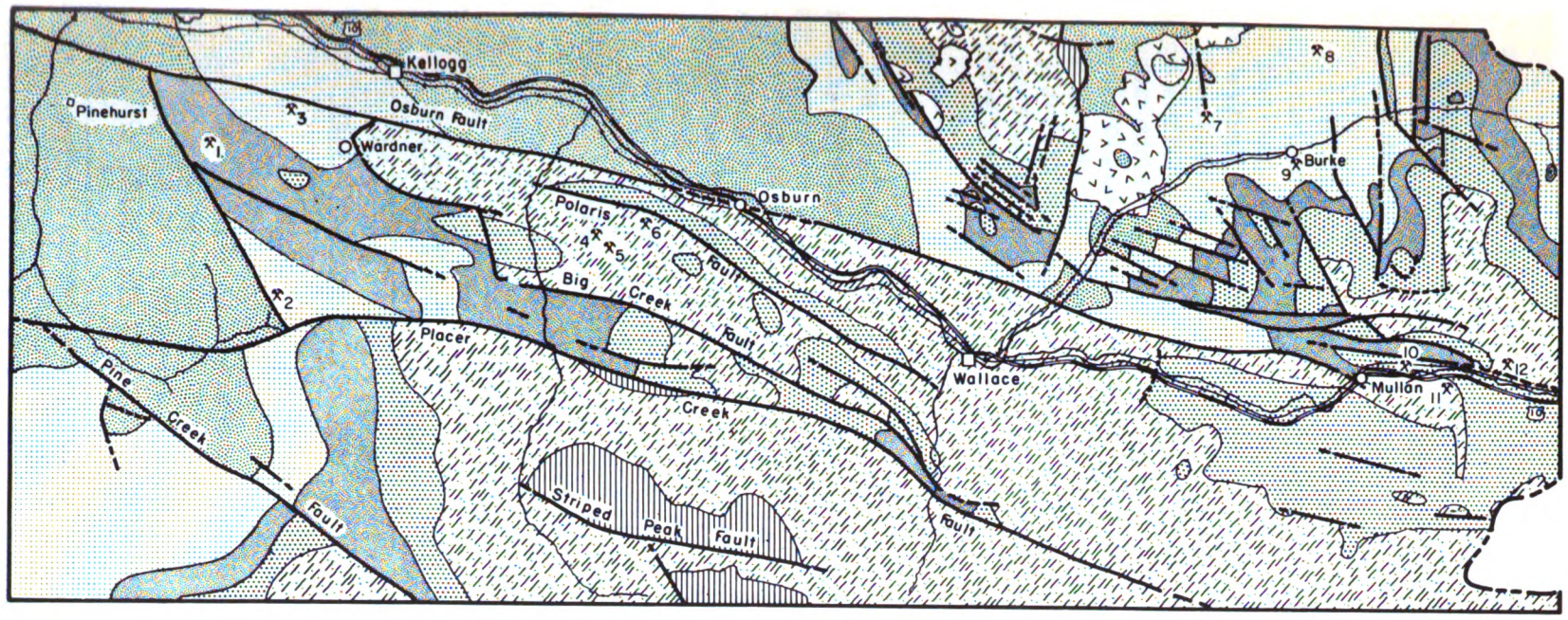

MINES

1.	Page	7.	Tamarack
2.	Sidney	8.	Hercules
3.	Bunker	9.	Star
4.	Crescent	10.	Lucky Friday
5.	Sunshine	11.	Atlas
6.	Polaris	12.	Silver Mountain

LEGEND

- Striped Peak
- Wallace
- St. Regis
- Revett
- Burke
- Prichard
- Monzonite

FIGURE 2. - Generalized Geology of the Coeur d'Alene Mining District.

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associated with fault zones and may occur as veins occupying fissures or as partial replacements in shear zones. The ore zones are generally steeply dipping; and the ore bodies, irregular in shape and erratic in distribution, may approach 130 feet in width and exceed 1,000 feet in length. Ore bodies have poorly defined limits and may have either a well-defined foot wall or hanging wall, but seldom both.

GENERAL MINING METHODS

The erratic occurrence and irregular shape of the ore bodies require considerable underground preparation before mining. Almost all exploration is accomplished underground by headings or by diamond drilling. Ore bodies are developed by crosscuts to the ore zone and by drifts and raises in the ore zone. Several standard stoping methods include square sets, cut-and-fill, stull sets and fill, and open stopes. The last-named method is probably least important for tonnage, as few Coeur d'Alene ore bodies are in sufficiently firm ground to stand without support. Cut-and-fill stoping with or without temporary support is rapidly gaining favor, particularly in mines utilizing mill tailings for backfill.

DRIFTS AND CROSSCUTS

All stoping methods require considerable preparatory development, including drifting, crosscutting, and raising. Size of the drifts and crosscuts is determined by the purpose they will serve and by the type and capacity of the equipment that will be used to drive and service the heading. The normal drifting and crosscutting cycle includes wetting and baring-down, mucking, and laying track. This is followed by installation of ventilation, air and water lines, as needed. Timbering and rock bolting, where necessary, is done before drilling, loading and blasting. A cycle is usually completed within an 8-hour shift by a crew which ordinarily consists of two men in untimbered headings and three men in timbered headings.

The following table is based on time studies in 13 headings.

TABLE 1. - Time distribution in driving drifts and crosscuts

	Untimbered heading, percent of time	Timbered heading, percent of time
Drilling.....	24	12
Set up and tear down.....	5	6
Load and blast.....	9	12
Mucking.....	31	31
Track and ventilation....	4	4
Timber.....	-	21
Other.....	27	14
Total.....	100	100

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Mucking

Except for one drift, which employed an electrically operated slusher, shoveling in all headings included in this report was accomplished with air-operated overshot loaders having capacities of 4.5 to 6.0 and 7.5 to 10.0 cubic feet. The mucking rate was from 54 to 210 cubic feet per man-hour and varied according to the size of mucker, width of opening, size and number of cars, method of car transfer, and distances that cars traveled. Average time for mucking a 50-cubic-foot car was 7.9 minutes, of which 2.3 minutes were spent loading, 2.8 minutes switching, and 2.8 minutes tramming.

The smaller loader requires a minimum headroom of 66 inches and has a cleanup range of 75 inches without side plows. Its loading speed is 20 to 35 c.f.m., depending upon the kind of material handled. The larger loader has a loading speed of 35 to 50 c.f.m. and requires headroom in excess of 89 inches. Its cleanup range is 88 inches without side plows. In some headings the opening is wider than the cleanup range of the mucker. In such instances, it is necessary to install short rails at an angle to the main track or to clean up by hand. Either method will cause a definite increase in mucking time.

Rocker-dump, bottom-dump, and side-dump cars are used in the district, but the most common are the Ajax 30- and 50-cubic-foot side-dump cars with capacities of 2.5 to 5.0 tons.

Three methods of car switching are employed: Gantry crane or overhead car transfer, Canton car transfer, and wye or switch. Both the overhead car transfer, known locally as a cherry picker, and the Canton car transfer are portable (fig. 3). The overhead transfer is an airlift hoist traveling on a beam near the roof of the heading. An empty car is raised by the hoist and transferred to a recess in the wall of the heading; the loaded car is then pulled back, and the empty is returned to the track ahead of the loaded car (fig. 4). The Canton transfer does the same job as the overhead transfer but travels on the bed or floor of the heading. Location of the transfer point has a direct bearing on the mucking cycle. Distances greater than 200 feet from the face cause the mucker to be idle much of the time. Other factors that may be important in the mucking cycle are the number of cars available and the distance to the disposal area. With enough cars available at the transfer point to handle the round, repeated trips to the disposal area are unnecessary.

Drilling

Hydraulically or pneumatically operated jumbos with 2-5/8-, 3-, or 3-1/2-inch automatic feed drifters mounted on aluminum-alloy shells are used in the district. The use of jumbos rather than columns and crossbars results in faster, safer, and more efficient setups. Figure 5 shows a company-made jumbo in operation. Figure 6 illustrates the jumbo collapsed for transportation. Figure 7 shows a hydraulic-boom jumbo at a drift face. Most of the air-boom jumbos were made by the mining companies. The hydraulically operated jumbos are manufactured commercially.

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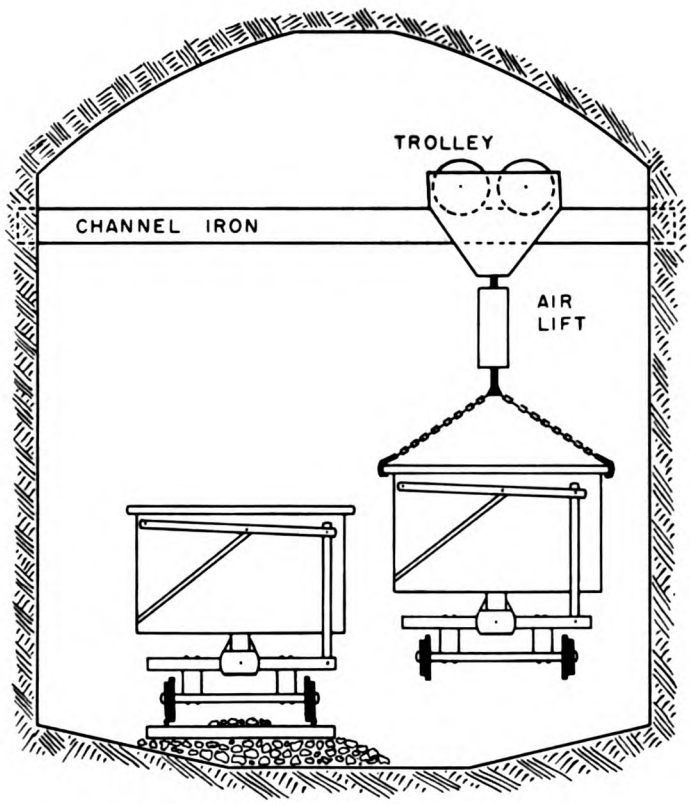

GANTRY CRANE (OVERHEAD)

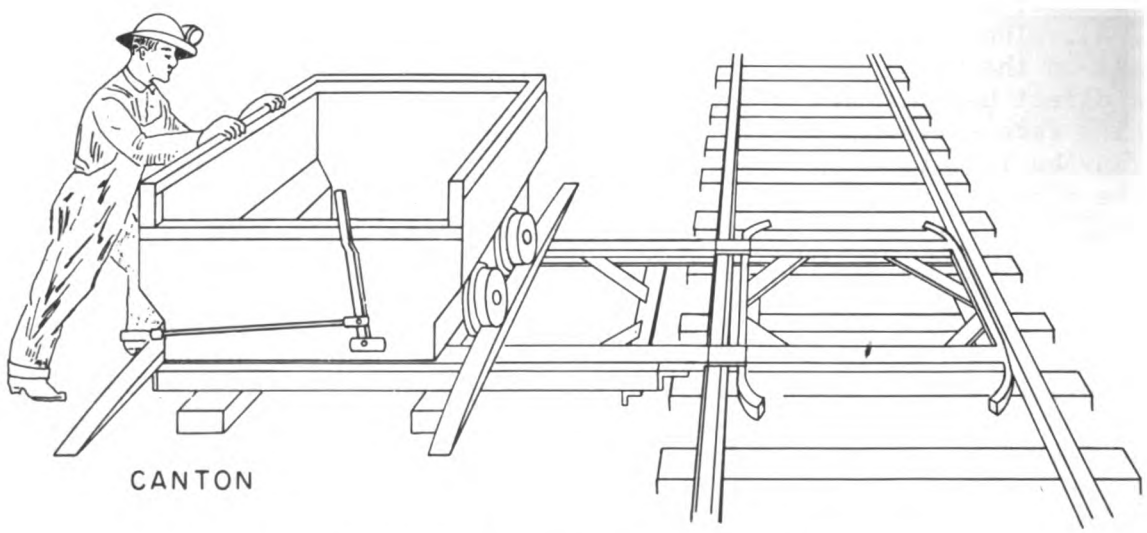

FIGURE 3. - Car Transfer Methods.

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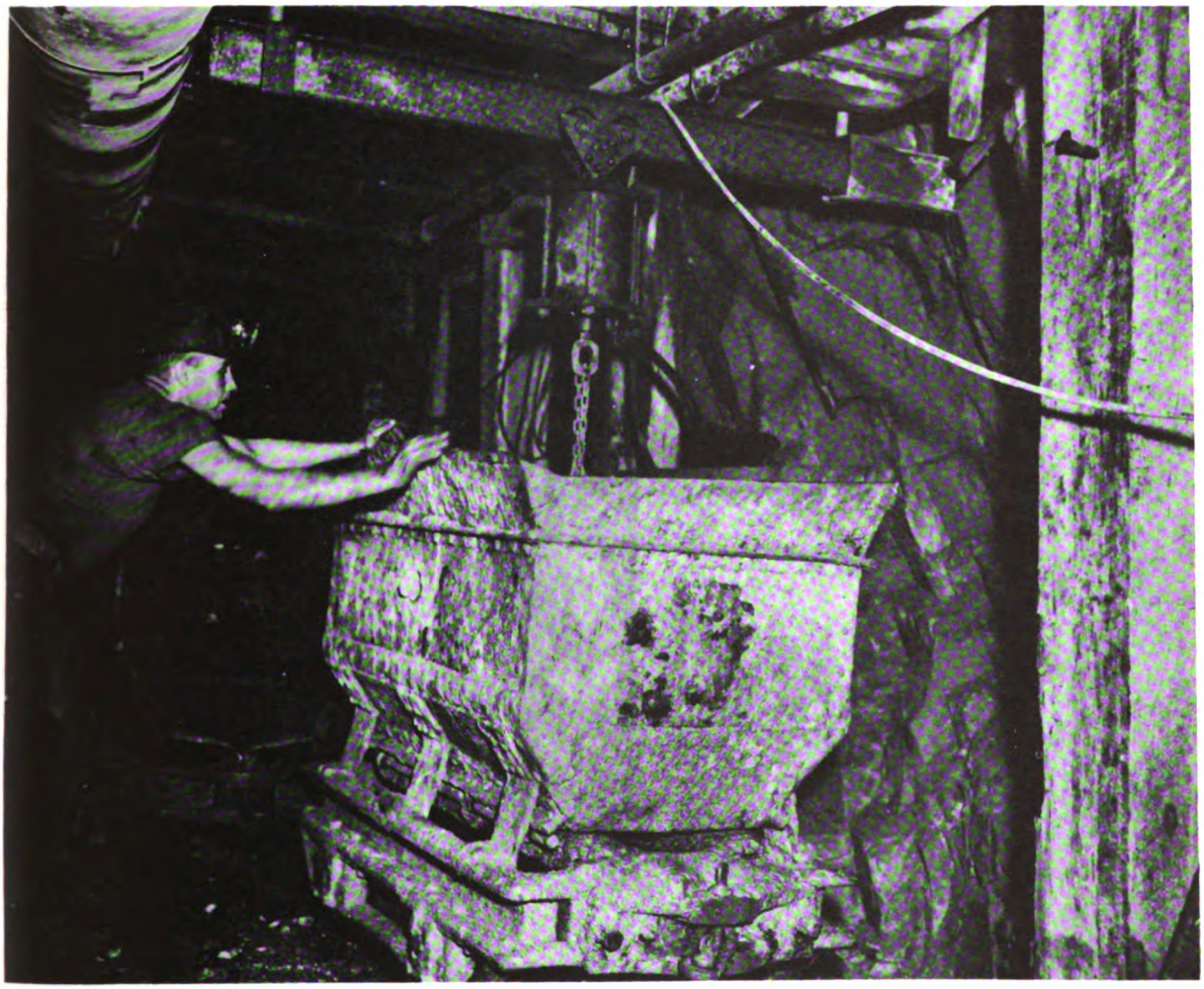

FIGURE 4. - Overhead Car Transfer.

Both round and hexagonal drill steel is used with drifters. Round steel is usually 1-1/8-inches in diameter and may be either carbon or alloy. Hexagonal drill steel may be 7/8 or 1 inch in diameter and is available as an alloy. Steel changes depend upon the size of the shell and range from 36 to 54 inches. Starter steels are usually 36 inches long. Two types of bits are used--detachable four-wing tungsten carbide insert bits, and throwaway four-wing steel bits having a starting gage of 1-3/8, 1-1/2, or 1-5/8 inches. Tungsten carbide bits are resharpened by shop personnel with the gage reduced 1/16 inch each time. Penetration rates vary from 15 to 31 inches per minute. Airleg-mounted drills, occasionally used for drifting and crosscutting, use 7/8-inch-diameter, round alloy steel and integral tungsten carbide chisel bits with a starting gage of 1-9/16 inches.

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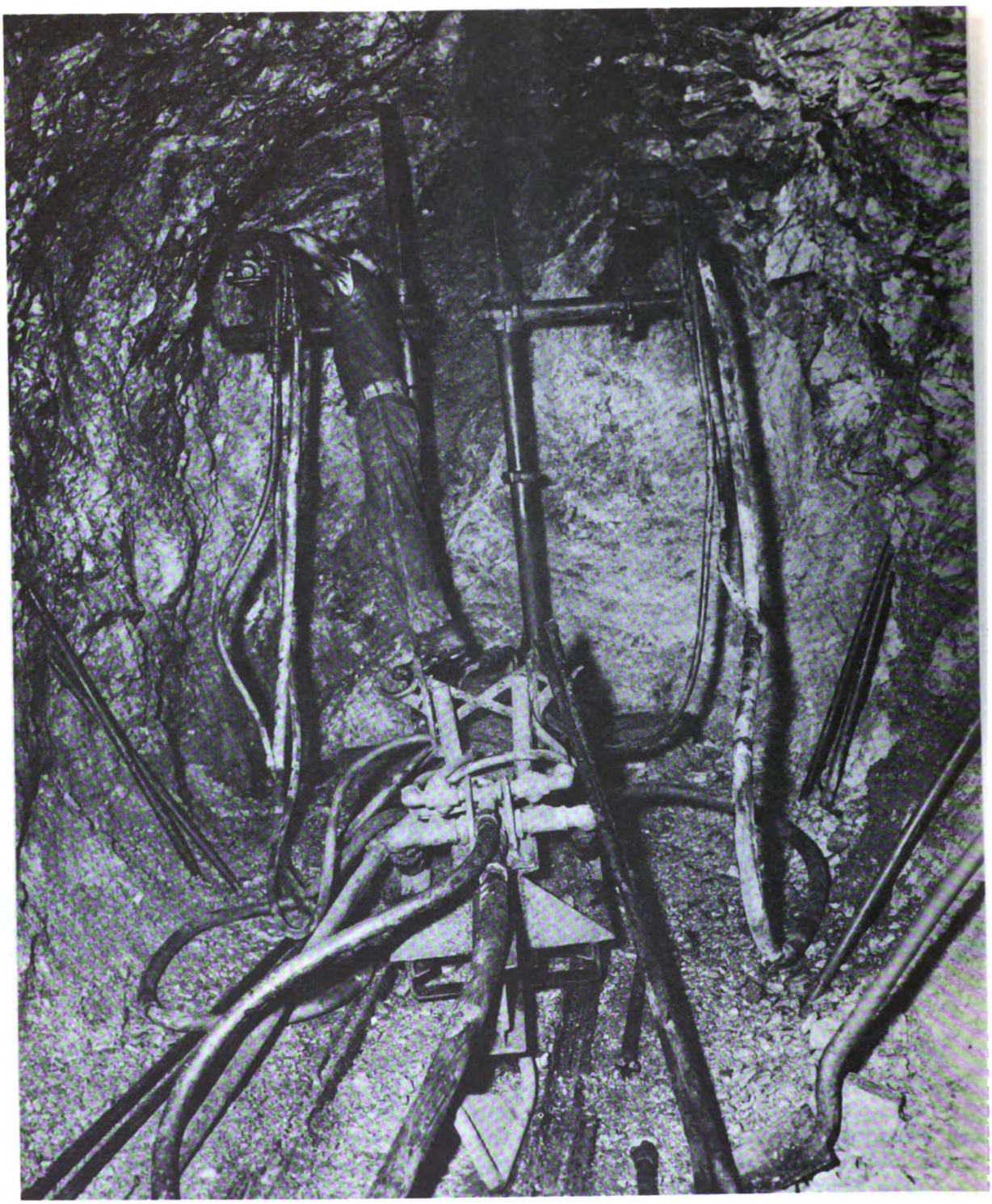

FIGURE 5. - Company-Made Jumbo.

Pyramid, burn, and variations of the V-cut rounds of 26 to 54 holes from 5 to 8 feet deep are drilled. Of the numerous cuts used in drifting and cross-cutting, only the pyramid and burn were reported to bootleg.

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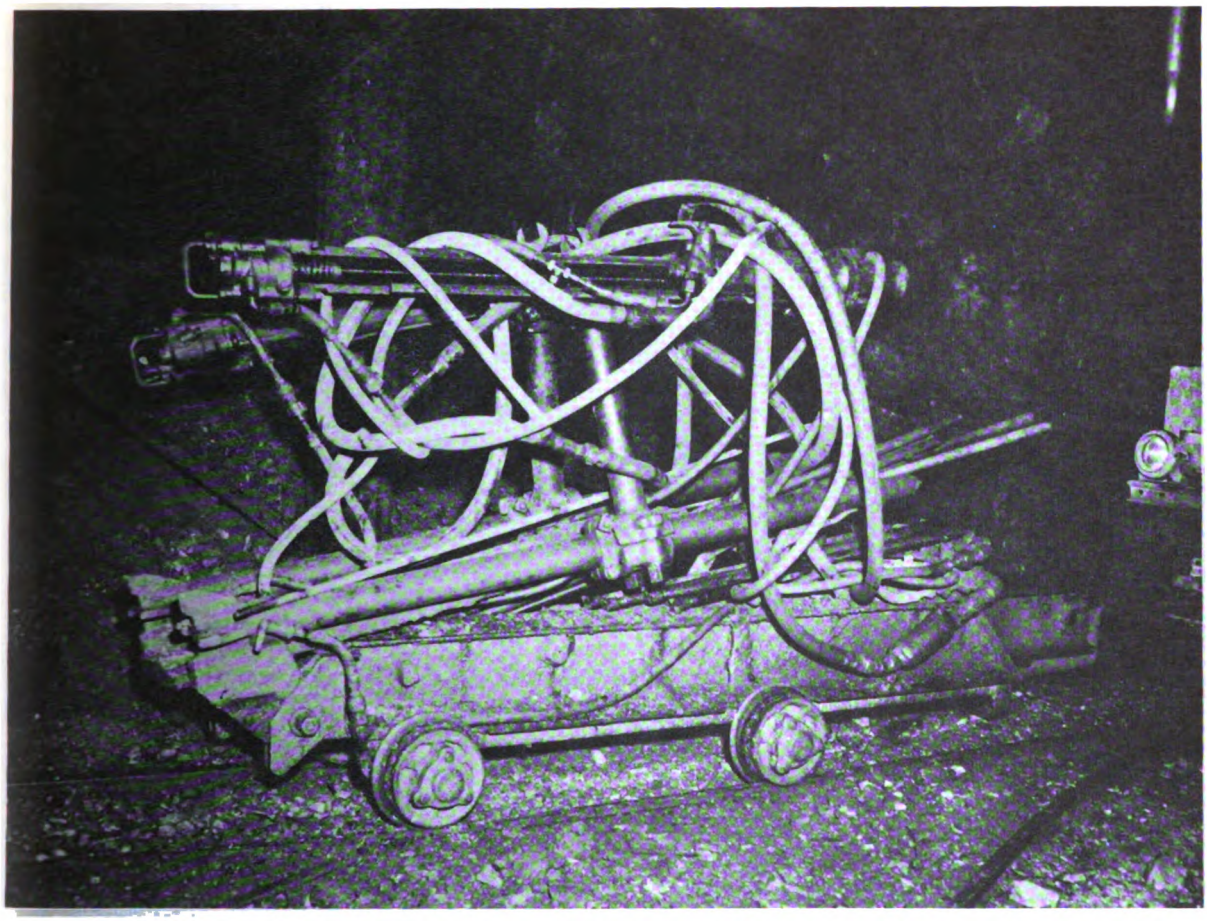

FIGURE 6. - Company-Made Jumbo Collapsed for Transportation.

Loading and Blasting

Several types of explosive are used. Gelatin dynamite in 40-, 45-, 50-, and 60-percent strengths is employed in hard-tight ground where maximum shattering effect is desired and in areas of dampness; if ventilation poses a problem, a low-density nitrostarch is employed.

Two types of detonators are employed--safety fuse and caps, and electric caps with regular and millisecond delays. Ignition of the safety fuse is accomplished by individual and bunch ignition, and by an ignitor cord. Electric firing is done by a blasting circuit from the main powerline or by a blasting battery. The blasting circuit is checked with a galvanometer to insure a closed circuit. After each round an inspection of the face is made for missed holes, which are washed out with water.

Supporting Operations

Timbering and Rock Bolting

Timber, rock bolts, and occasionally both, are installed where ground support is necessary. Drift sets are usually installed on 5-foot centers and

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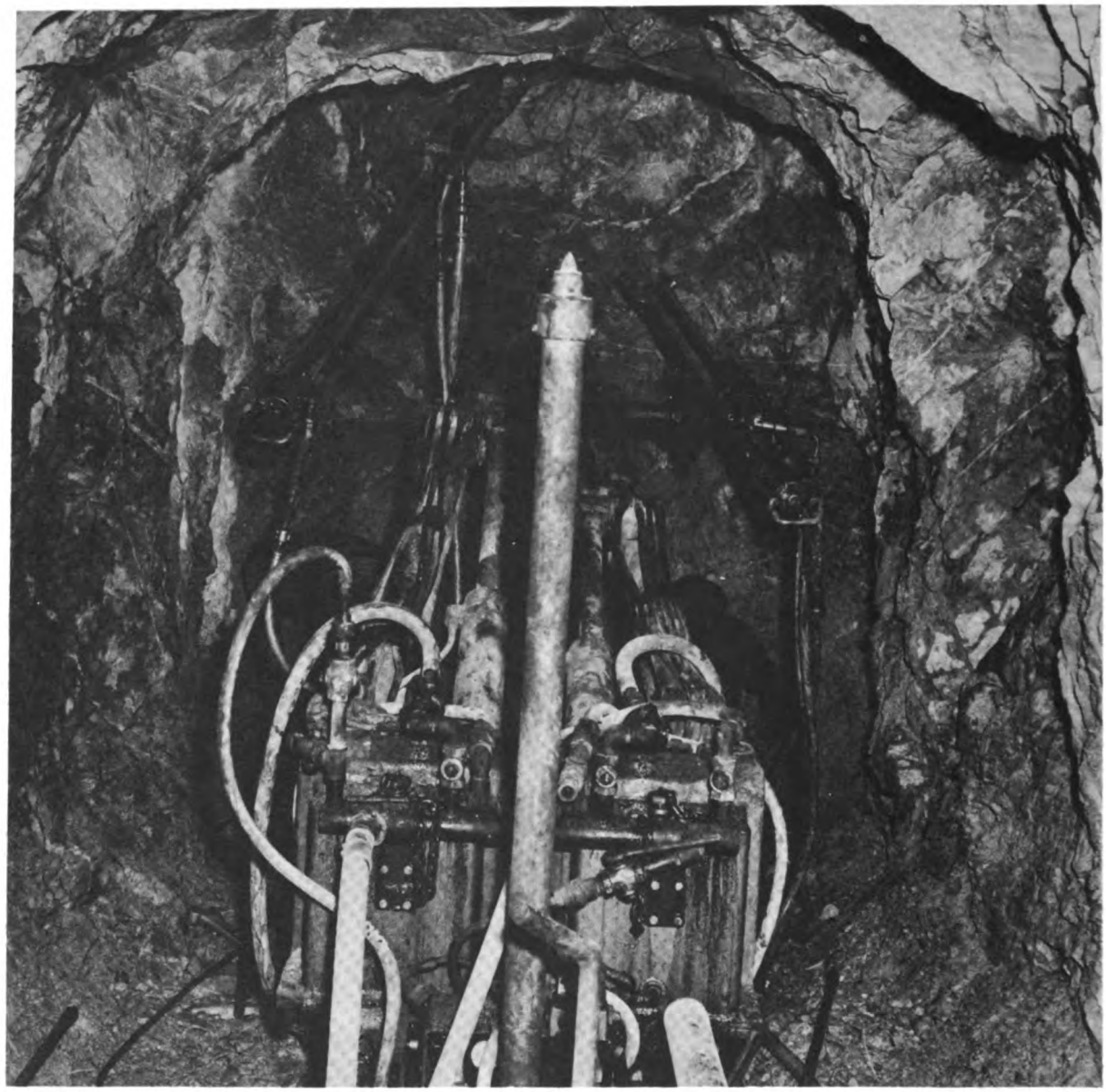

FIGURE 7. - Hydraulic-Boom Jumbo.

may vary in width from 6 to 18 feet. The wider sets are used in stope development drifts, mined the full width of the ore body. Posts are about 100 square inches in cross section, 9 feet long, and may be round or square. The caps are about 100 square inches in cross section and are long enough to allow for a minimum of 12 inches of blocking on each end. As much as 24 inches of blocking is used on each end of the cap when extreme side pressures are expected. Girts, 3 by 6 inches in cross section and at least 4 feet in length, are placed between the posts and spiked in place just beneath the caps. Three-

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inch lagging is laid across the top of the caps and the set is blocked tight (fig. 8). Time consumed in installing one set, for 5 linear feet of advance varied from 1.56 to 9.45 man-hours.

In headings where rock bolts are used, either 4- or 6-foot expansion shell or wedge-type bolts are installed with 3/8-inch steel bearing plates. A stoper is used for drilling, and an impact wrench is used to obtain the desired tension. Bolts are installed at random or in a fanlike pattern on 4-foot centers. For the latter, individual bolts are on 2.5-foot centers and are fanned from hip height up the wall, across the back, and down the other wall (fig. 9). Bolts are installed on company time, or under contract at a price of $2 per bolt.

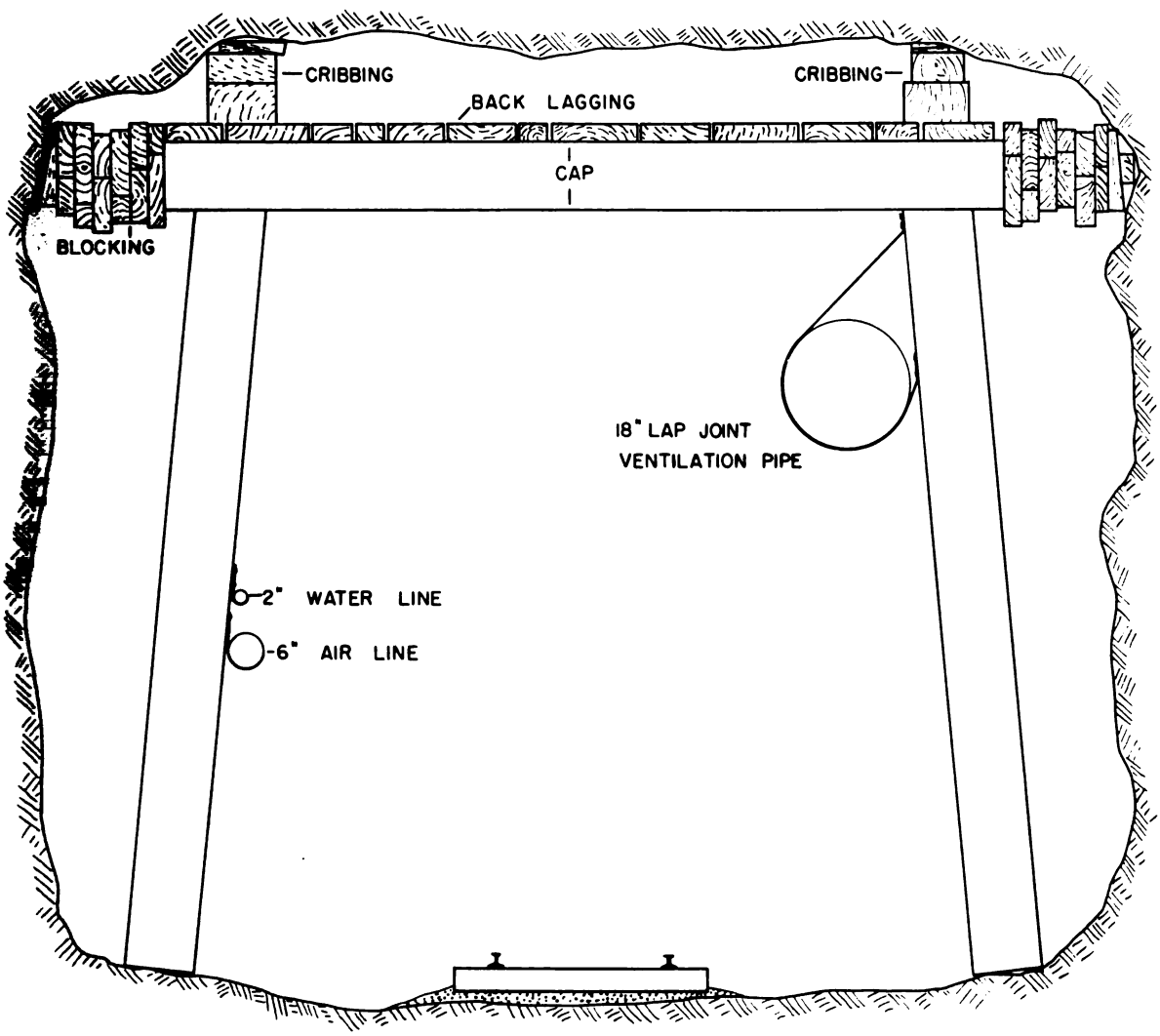

FIGURE 8. - Typical Drift Set.

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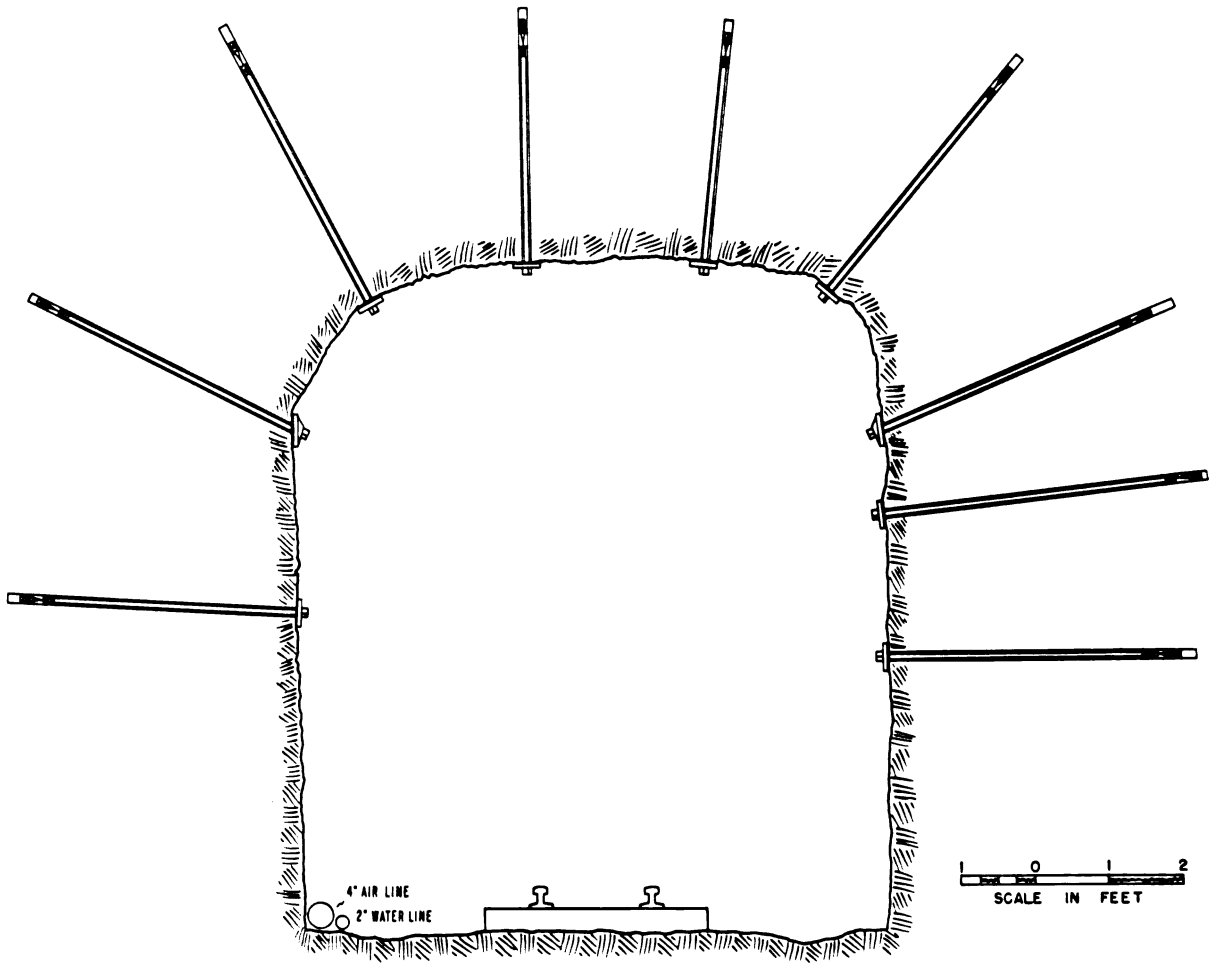

FIGURE 9. - Rock-Bolt Pattern at Sunshine Mine.

Tramming

Air-operated and battery-powered motors haul the broken rock from the face of the headings to loading pockets at the station. The distance varies from 100 feet to 2 miles. Battery-powered motors, capable of completing an entire shift, are employed on the longer hauls. A battery charger is usually at or near the shaft station to recharge the batteries on the off shift. Air-operated motors are used on hauls under 1,000 feet.

Track gage is usually 24 inches, but some mines install an 18-inch gage. Twenty- to forty-pound rails are laid on wood ties spaced approximately 24 inches center to center. Under most contracts, the miners are responsible for laying track on grade. Otherwise, the headings are driven subgrade, ballasted and brought to grade by trackmen.

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Ventilation, Air and Water Lines, and Drainage

Ventilation is accomplished by axial flow fans installed in series along the strike of the heading. Eighteen-inch, lap-seamed ventilation pipe is normally used, although 15-inch lap-seamed or 20-inch spiral weld pipe may be installed in specific instances.

Compressed air and water lines are carried to within 50 feet of the face. Main air lines are 4 to 6 inches, and water lines 2 inches in diameter. Compressed air is supplied to drill jumbos and mucking machines through 1-1/4- to 2-inch bull hoses. A 1-inch water hose provides water for drilling and for wetting down after blasting. Both threaded and victaulic couplings are used. Average length of air and water hose is 100 feet.

Drainage is not usually a problem, but where a ditch is necessary an extra (ditching) hole is included in the drill round. It is usually drilled about 6 inches below grade.

RAISES

Main raises have two or more compartments and are used for access between levels and for the exploration and development of ore zones. Small raises with 1 or 1-1/2 compartments serve for ore and waste passes.

Drilling, loading, and blasting is completed in larger raises in one shift. Timbering, installation of supply lines, and other work require an additional shift. In smaller raises, usually untimbered, the cycle is completed in one shift.

All raising in the Coeur d'Alene district is done under contract. In the larger raises, three men are employed--two at the face, and one on the sill to act as nipper, securing and hoisting supplies and sometimes tramming muck to the station. In the smaller raises, two men are employed.

TABLE 2. - Time distribution in driving raises

	Large raises, percent	Small raises, percent
Erect bulkhead.....	8	-
Set up and tear down.....	6	14
Drill.....	20	53
Load and blast.....	7	9
Clean down.....	10	-
Timber.....	22	-
Other.....	27	24
Total.....	100	100

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Drilling, Loading, and Blasting

Several sizes of automatic rotating stopers, 2-3/4- and 3-1/8-inch, are used for drilling raise rounds. Heavier drills are employed in the tougher ground. Hexagonal and quarter-octagon, 7/8-inch alloy drill steel is used with 18-inch changes. The starter steel is usually 30 to 36 inches long but occasionally it may be necessary to employ shorter steel. Four-wing detachable tungsten carbide insert bits, starting with 1-5/8-inch gage and reducing 1/16 inch for each change in steel are used in raising. Bits are reground and gaged by shop personnel or, in some mines, by an underground mechanic. Penetration rates varied from 14 to 32 inches per minute. Burn and V-cut rounds of 22 to 56 holes are drilled to depths ranging from 5.8 to 7.5 feet. The V-cut round is used in larger raises, and the burn cut in the smaller raises.

Low-density nitrostarch explosive and gelatin dynamite 1-1/8-inch by 8-inch cartridges are used. Detonation is by safety fuse and cap or by electric delays. No stemming is used, as holes are loaded to the collar.

As soon as drilling is completed, bulkheads are erected over the inner compartments to reduce damage from blasting and to prevent muck from entering the two inner compartments. The most common type is made of three layers of 3-inch lagging nailed skin to skin. The lagging is later used to erect staging to land and install timber. Spillage occurring in the manway and hoisting compartment is cleaned down during the period of drilling.

Muck disposal may differ in raises. In some instances a minimum of material is withdrawn from the chute to prevent excessive damage to the chute and manways and still allow sufficient room for the next round. Some mines install a control chute midway from the lower sill to the face, so that drawing off is controlled by the raisemen. In untimbered raises the chutes are pulled empty.

Timbering

A four-compartment, three-cap raise with untimbered outside chutes requires six 6- or 8-inch square posts, three 8- or 10-inch square caps, and four 3 by 6 inch girts. The posts and girts are 4 feet 2 inches long for 10-inch caps and 4 feet 4 inches long for 8-inch caps. The caps are cut to fit the ground, usually allowing 9 inches of blocking at each end. Three-inch lagging is used for lacing and bulkheads. One of the two inner compartments is used as a manway, and the other as a service compartment containing the timber slide and air and water lines. The two outside compartments are used for ore and waste passes (fig. 10).

Auxiliary Operations

Air, water, and ventilation lines are installed in the larger raises on the same shift that timber is set; in the smaller raises the lines are installed as needed. Main air and water lines are 2 inches in diameter and are carried approximately 25 feet from the face. Shutoff valves are at the bottom of the raise and at the main line outlet. All connections are made by victaulic couplings.

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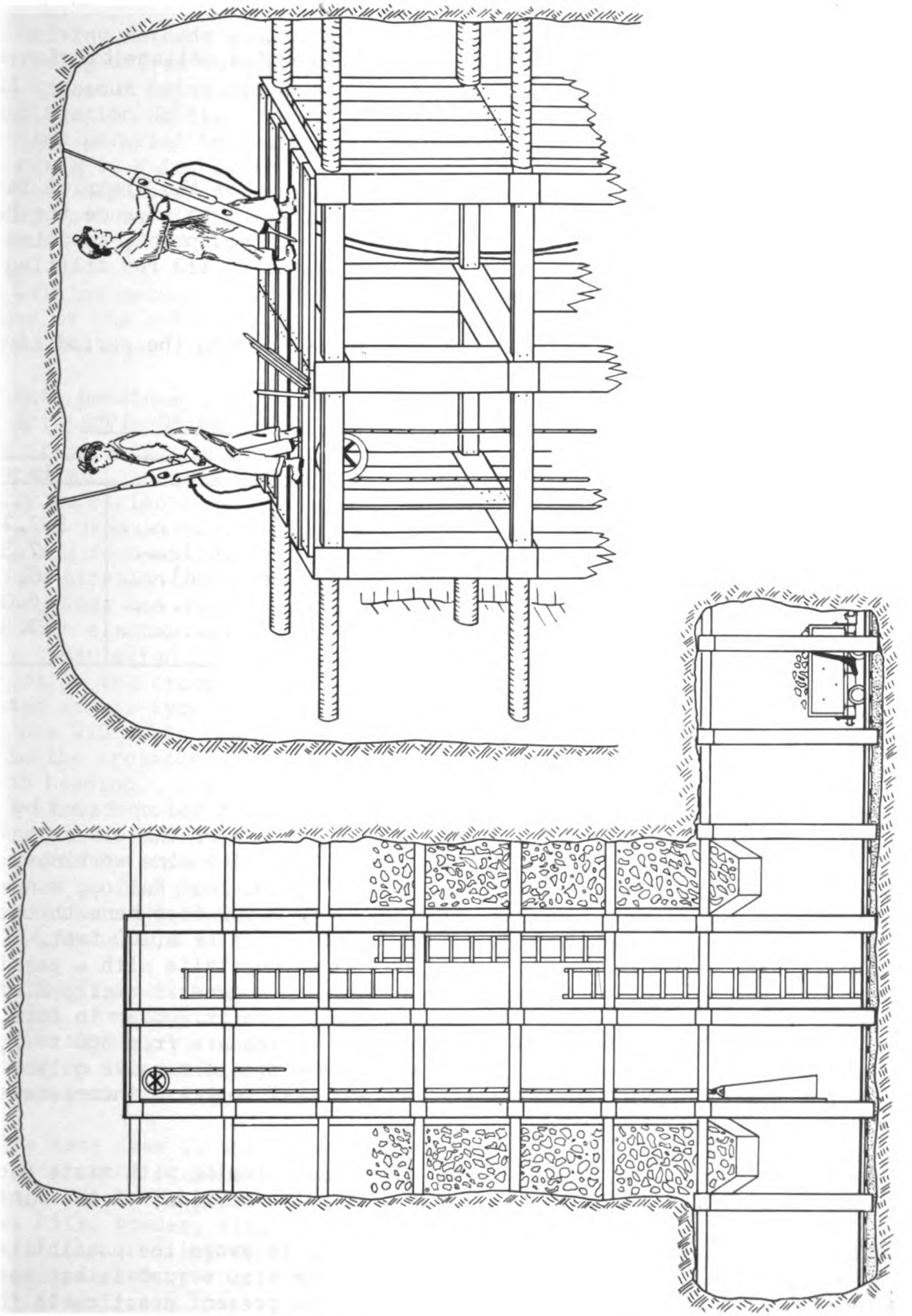

FIGURE 10. Four-Compartment Raise (Lucky Friday Mine).

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Forced ventilation at the face is obtained through a collapsible fan bag from a blower fan at the bottom of the raise.

LABOR

Most exploration and development work in the mines of the district is done by contract. The miners furnish all labor necessary to advance the heading efficiently and safely. The company furnishes all equipment, supplies, and incidentals. Price paid per foot of advance is $8 to $13 for drifting and crosscutting, and $10.90 to $35 for raising.

The following average wage rates were in effect during the period covered by this report.

TABLE 3. - Wage rates in effect July 1, 1957-June 30, 1958

Job description	Daily wage	Job description	Daily wage
Timberman.....	$18.74	Cager.....	$17.74
Drift miner.....	18.74	Trackman (unskilled).....	17.30
Raise miner.....	18.74	Helpers (underground)....	16.74
Mucking machine man.....	18.18	Mucker (hand).....	16.30
Trackman (skilled).....	18.18	Motorman.....	17.30

DRIFTING AND CROSSCUTTING

Bunker Hill Mine

Surface installations of the Bunker Hill mine, owned and operated by The Bunker Hill Co., are in Kellogg, Idaho. The mine is one of the oldest in the district and has been continuously active since 1885. The mine workings, southwest of the portal, are reached through the 12,000-foot Kellogg tunnel. Workings extend from 1,500 feet above the tunnel to 3,600 feet beneath the tunnel (1,200 feet below sea level), a vertical distance of 5,100 feet. Ore deposits are associated in the St. Regis and Revett quartzite with a persistent mineralized fissure (the Bunker Hill fissure) having a general strike N. 45° W. and dip 35° to 45° SW. Many ore bodies of the mine are irregular in form and lie at an angle to the Bunker Hill fissure. Ore bodies are from 300 to 1,000 feet in length and may be 30 to 125 feet wide. The ore is massive galena with siderite and quartz as gangue. Both the ore and wall rock are incompetent and require immediate ground support.

The mining method in general use is square-set stoping with waste backfill. Modifications have been made to fit particular sections of the mine.

Exploration drifts are driven in the ore zone to avoid the possibility of missing an ore shoot. Until recently, these drifts also served as haulageways, and some are still used to serve older stopes. The present practice is to drive service and transportation entries in the footwall to avoid expensive maintenance of timbered drifts through stoped areas.

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Driving methods were observed in two headings--one, a timbered footwall drift being driven to service a newly opened stope, and the other, an untimbered crosscut being driven to intersect the ore zone and serve as access to an exploration drift. The footwall drift is being driven 10 feet wide by 12 feet high parallel to the bedding in medium-soft, argillaceous quartzite. The beds are 2 to 4 inches thick and dip 50° to 90°. The crosscut is 9 feet wide by 9 feet high and intersects the bedding at about 30° to the strike plane. Country rock is similar, except that the quartzite is somewhat harder in the crosscut.

Driving methods are similar in both headings, and differ in detail mainly because of the difference in sizes of the headings and in hardness of the ground.

Both headings employ a V-cut round, drilled with two 3-inch automatic feed drifters mounted on a shop-made jumbo. The drift round consists of 26 holes drilled to a depth of 6 feet. Harder ground in this particular crosscut required a 38-hole round drilled to 7.5 feet, although a 32-hole round is usually sufficient. Round 1-1/8-inch alloy steel, heat-treated in company shops, is used in both headings. Throwaway bits (1-5/8-inch) are used in the drift, and four-wing, 1-3/8-inch tungsten carbide bits are used in the crosscut. Penetration rates are 21.5 and 16.0 inches per minute, respectively. Both headings use 45-percent gelatin dynamite loaded to the collar and detonated with electric delay caps in the sequence shown in figures 11 and 12. Powder consumption is 14.6 pounds per linear foot in drifting and 21.9 pounds per foot in the crosscut. Both headings are mechanically mucked with air-operated rocker-type shovels of 7.5 to 10.0 cubic-foot capacity. Mucking rates are 210 cubic feet per man-hour in the drift and 165 cubic feet per man-hour in the crosscut. Eight 64-cubic-capacity bottom-dump cars are assigned to each heading. A small air-operated trammer operates in the crosscut, and a full-size, 5-ton battery locomotive is used in the drift. Loaded cars are trammed 150 to 300 feet to a switching point, which may be a junction with another heading or an overhead car transfer. Loaded cars are held in the heading or at the switching point until a full train is assembled, and then are trammed to the shaft station by the miners. Track gage and weight are the same (24 inches and 40 pounds per yard) as in other parts of the mine.

Timber is not ordinarily required in the crosscuts, but is always required in drifts. Regular drift sets are installed in drifts and also in the crosscuts when necessary. Drift sets contain three members--two posts and a cap--preframed on the surface of 10- by 12-inch or 12- by 14-inch Douglas fir. Sides and back are lagged with 2-inch-thick fir and larch.

The face crew in each heading consists of two men driving the heading, under a contract agreement specifying the amount to be paid per foot of advance. The company provides all equipment and supplies, including drills, steels, bits, powder, air, water, etc.; and the contract crew performs all phases of the drifting cycle, except laying track and utility lines. In this they are assisted by a trackman who also acts as nipper in bringing supplies to the face.

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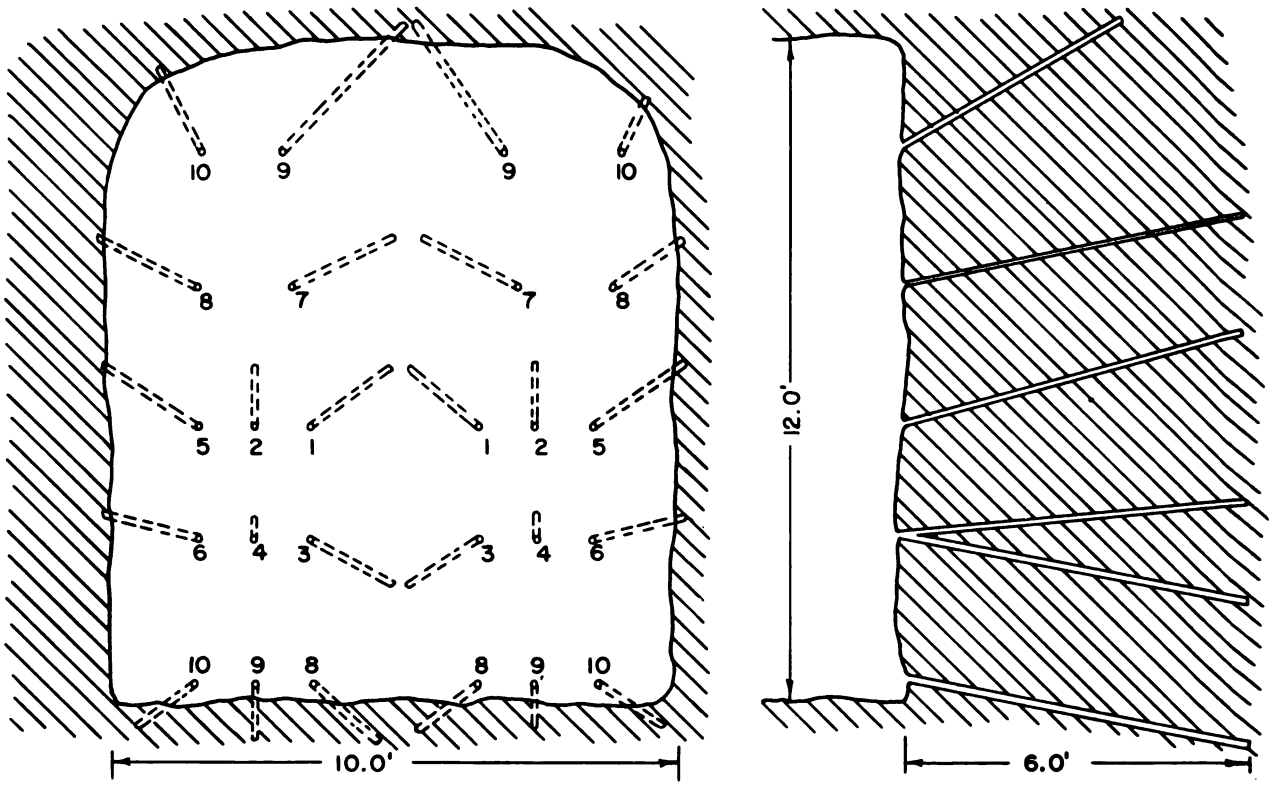

FIGURE 11. - Drift Round, 18 Level (Bunker Hill Mine).

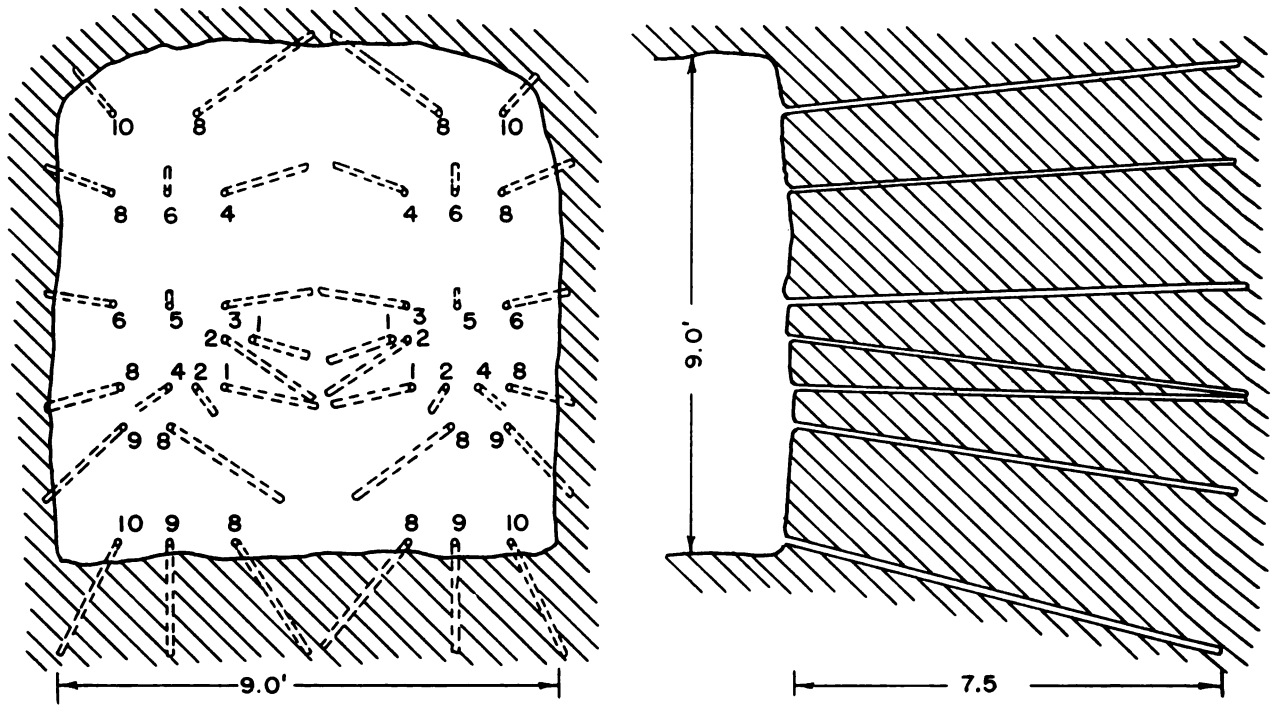

FIGURE 12. - Crosscut Round, 21 Level (Bunker Hill Mine).

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In the 10- by 12-foot timbered drift the face was advanced one set per day on a one-shift basis by a two-man crew, or 2.96 feet per man-shift. The 9- by 9-foot crosscut was advanced an average of 6.46 feet per day, or 3.23 feet per man-shift.

Contract price per foot was $9.35 for untimbered headings and $11.10 for timbered headings.

Crescent Mine

The Crescent mine, owned and operated by The Bunker Hill Co., is 2.7 miles southeast of Kellogg, Idaho. The collar of the underground shaft, at an elevation of 2,709 feet, is in the Hooper tunnel about 4,000 feet west of the portal. Mining at the Crescent was begun before 1917 and continued until 1942, when the mine was closed by the scarcity of manpower and near exhaustion of the ore bodies. In 1953 and 1954 the underground shaft was deepened from 1,275.5 to 3,276.0 feet to permit exploration of the ore zone at greater depth.

A promising ore zone was found in shattered Saint Regis quartzite in the footwall of the Alhambra fault. The vein structure generally strikes east and west and dips south 45° to 85°. Mineralization consists of tetrahedrite and galena. Predominant gangue minerals are quartz and siderite.

Driving methods were observed in two headings, both being driven on the same vein--one on the 3100 level and the other on the 2500 level. Both are exploration drifts 9 by 9 feet in cross section. The 3100 drift was being advanced by two 2-man crews working on a two-shift basis; the 2500 drift by a two-man crew working one shift per day.

A V-cut round drilled with two 3-inch automatic feed drifters is used in both headings. A skid-mounted jumbo is used in the 2500 drift, and a track carriage is used in the 3100 drift. The number of holes per round varies from 38 to 43. All rounds are usually drilled to a depth of 8 feet. Round, 1-1/8-inch-diameter carbon steel, heat-treated in the company shop, with four-wing 1-3/8-inch detachable tungsten carbide insert bits, is used in both headings. Penetration rates are 18 to 15 inches per minute for the 3100 and 2500 drifts. Both headings employ 60-percent gelatin dynamite loaded to the collar and detonated with electric delay caps. Both millisecond and regular delays are used in the 3100 drift; only regular delays are used in the 2500 drift. Firing is done in the sequence shown in figures 13 and 14.

Two mucking methods are employed. The 3100 drift is mucked by a 7.5- to 10.0-cubic-foot-capacity, air-operated rocker shovel. Ten 64-cubic foot bottom-dump cars, powered by a 5-ton battery-operated motor, serve the drift. Cars are switched within 300 feet of the face by an overhead car transfer. Mucking rate, including tramming approximately 5,000 feet to the shaft station, averaged 155 cubic feet per man-hour in the 3100 drift. The 2500 drift is mucked by a 20-hp. electric slusher hoist with a 42-inch scraper. Maximum slushing distance is 100 feet on either side of the waste or ore passes. Muck from the 2500 drift is drawn from the ore pass on the 3100 level and trammed

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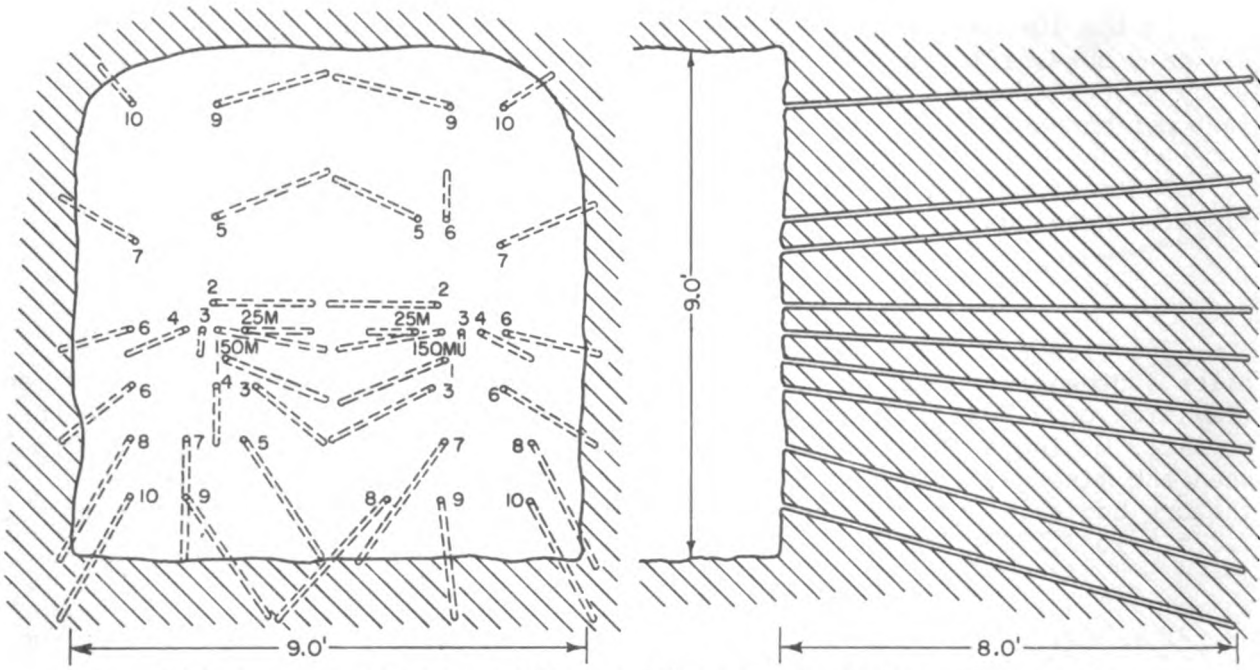
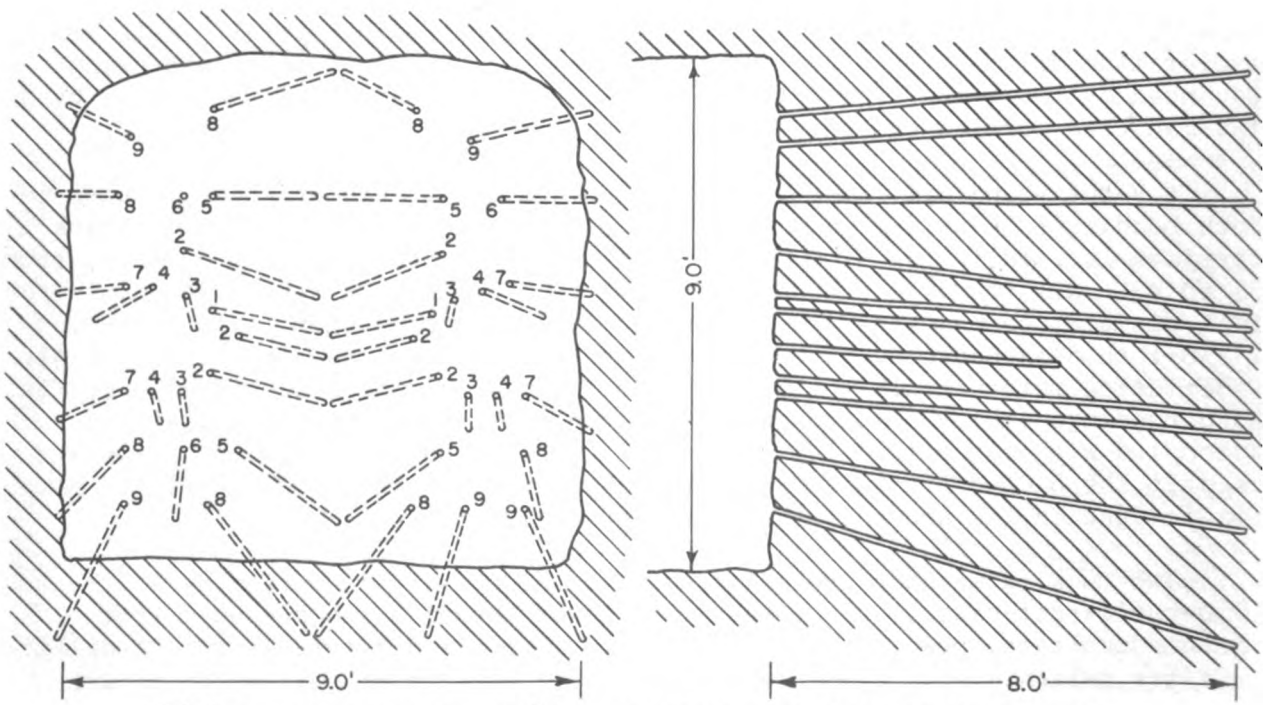


Firing sequence with millisecond delay detonation.



Firing sequence with regular – delay detonators.

FIGURE 13. - Drift Round, 3100 Level (Crescent Mine).

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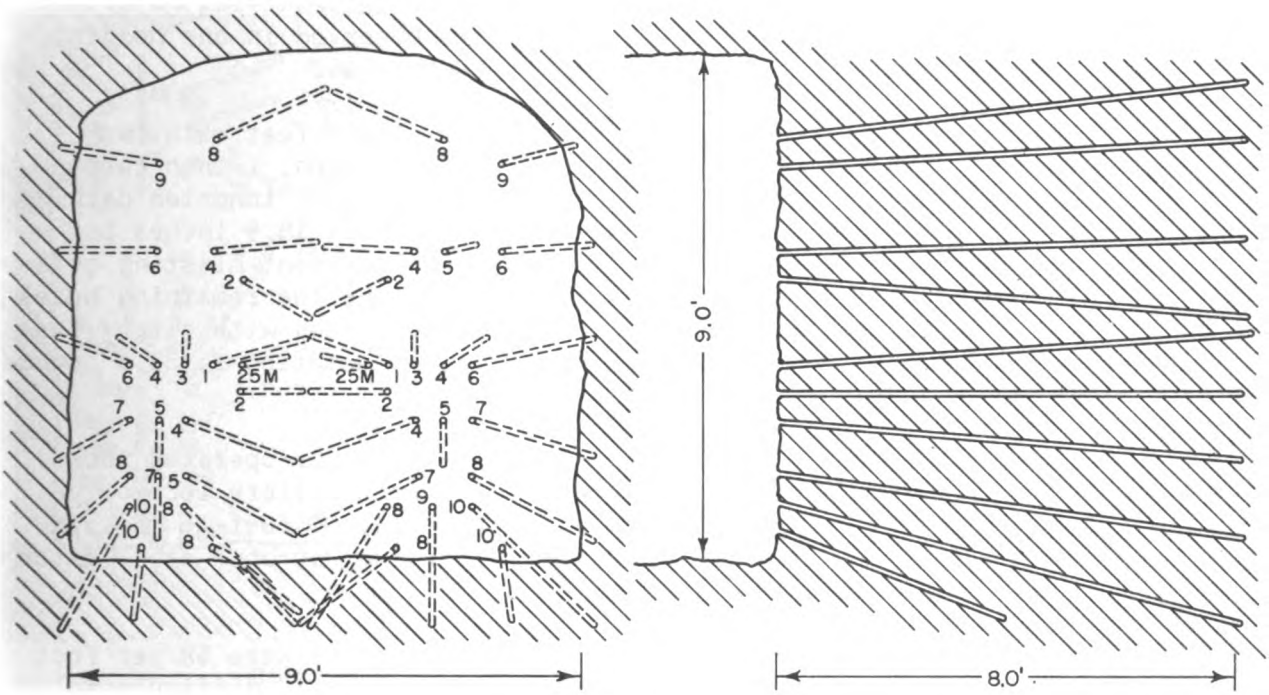

FIGURE 14. - Drift Round, 2500 Level (Crescent Mine).

to the station by a motor crew. Approximately 2.7 man-hours are required to clean out a round in the slusher drift.

The face crew in each heading consists of two men driving the drift at a contract price of $9.85 per foot of advance. All equipment and supplies are furnished by the company and delivered to the 3100 station. The trackman on the 3100 level assists the miners in installing ventilation lines in both headings and aids the miners on the 3100 level in laying track and installing pipe. He also acts as a nipper for both headings.

Advance in the 3100 drift averaged 3.85 feet per man-shift and 4 feet per man-shift in the 2500 drift.

Hercules Mine

The Hercules mine, owned by Day Mines, Inc., is near Burke, Idaho, and has been in continuous operation since 1901. Workings extend from the outcrop to the 1900 level, a vertical distance of more than 4,300 feet. Access to the workings is by an underground vertical shaft 8,500 feet from the portal on the main haulage adit. The shaft collar is about 2,400 feet below the surface, and the shaft reaches the 1600-foot level. A two-compartment winze sunk from the 1600 level, bottomed about 1,950 feet below the adit level. Exploration work from the winze was done by drifting and crosscutting.

Ore deposits above the 200 level are in the Burke formation, and below the 200 level are in the Prichard. The Prichard formation consists of

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flat-lying, hard and medium-strong, thin-bedded quartzite requiring no artificial support in the crosscuts. Driving methods were observed in one heading, a crosscut 8.0 feet wide by 8.5 feet high on the 1900 level.

A V-cut round of 54 holes is drilled to a depth of 6.5 feet with two 3-1/2-inch automatic feed drifters mounted on a jumbo. Round, 1-inch carbon steel of various lengths and four-wing, 1-5/8-inch detachable tungsten carbide insert bits are used in the heading. A penetration rate of 18.9 inches per minute is made. Holes are loaded to the collar with 45-percent blasting gelatin. Cut holes are bottom primed with 60-percent gelatin; the remaining holes are bottom primed with 45-percent gelatin. All are detonated with safety fuse and caps in the sequence shown in figure 15. Powder consumption is 33.5 pounds per linear foot.

The heading was served by a 7.5- to 10.0-cubic-foot, air-operated rocker shovel, two 50-cubic-foot side-dump cars, and a 1-1/2-ton battery locomotive. The mucking rate included switching and tramming about 1,200 feet to the station, and averaged 78 cubic feet per man-hour. Switching was done at a Canton car transfer about 250 feet from the face.

The heading crew consisted of two men. Contract prices were $8 per foot in waste rock and $10 per foot in hard, pyritic vein material, difficult to drill and break. All equipment and supplies were furnished by the company. In addition to the contract price, $0.61 per hour was added to the contract as a cost-of-living increment.

Originally the heading was advanced on a two-shift basis, but was later reduced to one shift per day to coincide with regular mine operations. Advance averaged 2.25 feet per man-shift, based on one shift per day.

Lucky Friday Mine

The Lucky Friday mine, owned and operated by the Lucky Friday Silver-Lead Mines Co., is 1 mile east of Mullan, Idaho. The mine is accessible to a depth of 3,050 feet from an underground shaft collared 200 feet from the portal of the supply adit. Level spacing below the 2000 level is on 150-foot intervals. The mine was discovered in 1899, but very little work was done until 1938, when the present company was formed. A considerable amount of exploration and development work has since been completed.

Ore deposits above the main adit, about 350 feet north of the No. 2 shaft, at the same elevation of the collar of the shaft, were found in the Wallace formation. Below the main adit, ore was found in the St. Regis and Revett formations. Mineralization in the Lucky Friday vein, which strikes roughly east and west and dips 60° to 85° S., consists of tetrahedrite, galena, and minor amounts of sphalerite. Width of the ore shoots remain consistent at 6 to 8 feet. The predominant gangue minerals are quartz and siderite.

Stopes are mined by horizontal cut and fill; ore is breasted-down and slushed into an ore pass near the center of the stope. Waste is passed from the upper levels through a raise, and the dry-fill is spread by slushing.

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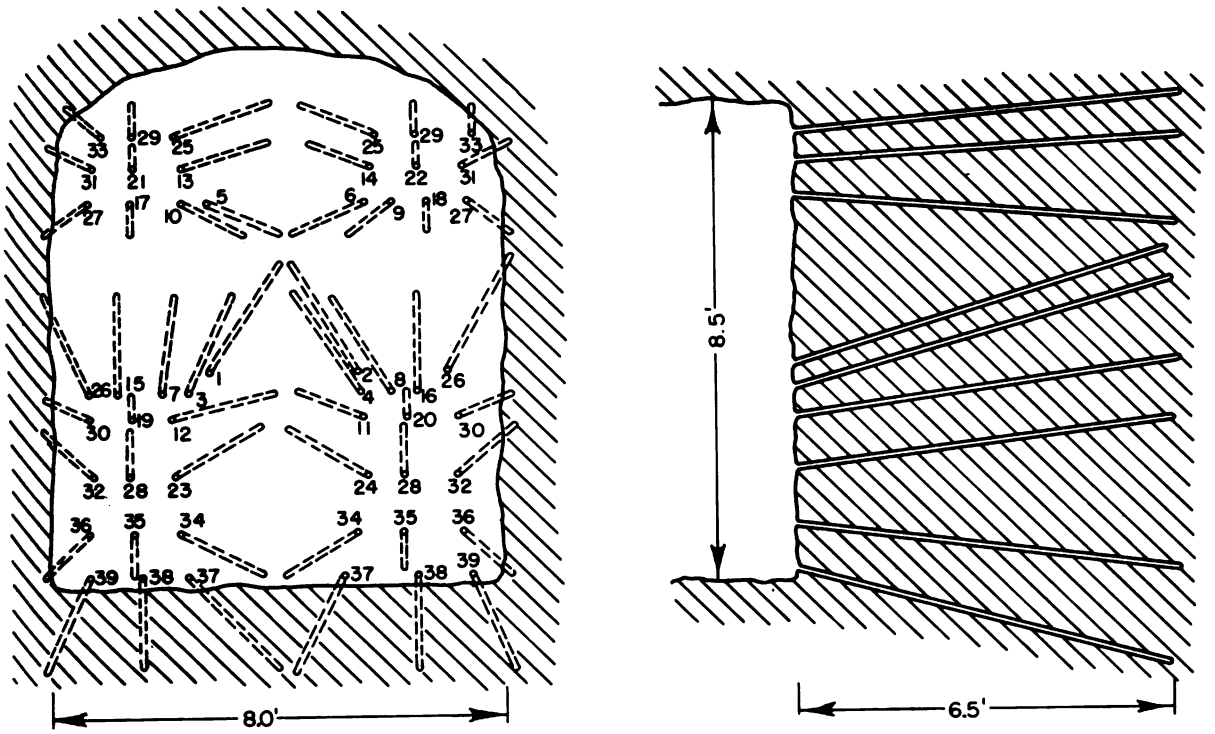

FIGURE 15. - Drift Round, 1900 Level (Hercules Mine).

Raise development is such that the maximum slushing distance for ore and waste is 100 feet.

Driving methods were observed in two headings, one a drift in a vein 8.0 feet wide by 7.5 feet high, and the other a crosscut normal to the strike of the bedding. The crosscut is 8.5 feet wide by 9.0 feet high, and will intersect the ore zone to serve as access to an exploration drift. The country rock is a hard quartzite in both headings.

Both headings employ a 33-hole burn-cut round, drilled with 2-5/8-inch airleg drills to a depth of 6.5 feet. Hexagonal, 7/8-inch alloy steel, 7 feet long, with an integral tungsten carbide chisel bit, 1-9/16-inch gage, is used in both headings. Bits are resharpened by the miners. Penetration rates measured 19.0 inches per minute for the drift and 22.1 inches per minute for the crosscut. Both headings use 40-percent blasting gelatin loaded to the collar and detonated with electric delays in the sequences shown in figures 16 and 17. Powder consumption amounts to 15.3 pounds per linear foot in the drift and 14.9 pounds per foot in the crosscut.

Air-operated rocker-type shovels with a capacity of 4.5 to 6.0 cubic feet are used in both headings. Mucking rates, including tramming to the station, are 78 cubic feet per man-hour in the drift and 115 cubic feet per man-hour in the crosscut. The face of the drift was about 800 feet from the station, and the crosscut face was about 100 feet from the station. Thirty-cubic foot, side-dump cars are assigned to each heading. Tramming to the ore pocket in the drift on the 2600 level is performed by a 1-1/2-ton battery locomotive. Tramming on the 3050 level was done by an air-operated locomotive for the

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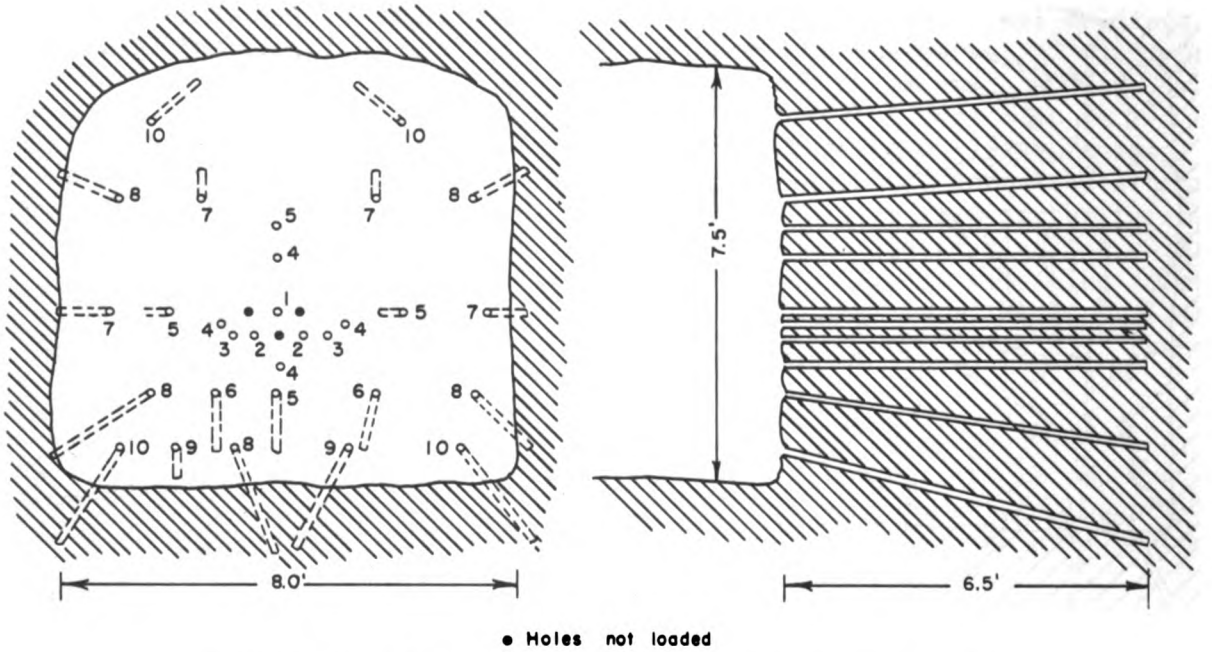

FIGURE 16. - Drift Round, 2600 Level (Lucky Friday Mine).

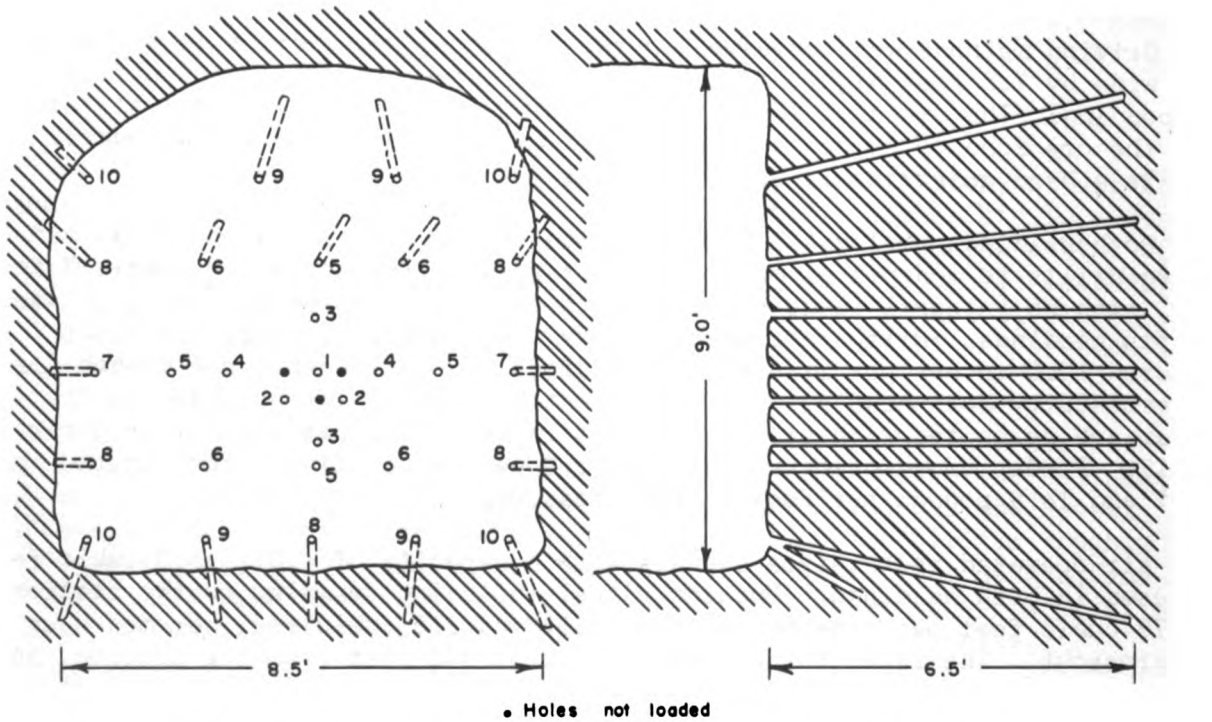

FIGURE 17. - Crosscut Round, 3050 Level (Lucky Friday Mine).

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initial 300 feet, then by a 1-1/2-ton battery locomotive. Track gage and weight are 24 inches and 20 pounds per yard on the 2600 level, and 24 inches and 30 pounds per yard on the 3050 level.

The face crew consisted of two men driving the heading under contract, with all equipment and supplies furnished by the company at the shaft station. The contract price varied between headings because of the difference in size, working conditions, etc. The rate was $10.50 per foot in the drift and $12 per foot in the crosscut. Average advances were 3.17 feet per man-shift in the drift and 2.98 feet per man-shift in the crosscut.

Page Mine

The Page mine, owned and operated by the American Smelting and Refining Co., is 3.8 miles southwest of Kellogg, Idaho. Mine workings are accessible through a 55° inclined shaft collared at an elevation of 2,677 feet above sea level and extending to 773 feet below sea level. Levels are spaced on a slope distance of 300 feet.

Ore deposits occur in the Revett and Burke formations in veins that strike south 70° to 80° W. and have a southerly dip of 40° to 60°. The ore minerals are galena and sphalerite associated with siderite in broken crushed-ore zones of various widths. Square-set stoping is the principal mining method.

Driving methods were observed in a drift 10 feet wide by 11 feet high in the ore zone. The country rock is hard and strong, and support is unnecessary except in fault or shear zones.

The miners used a 33-hole V-cut round, drilled to a depth of 5 feet with two 3-1/2-inch automatic feed drifters mounted on a jumbo. Round, 1-inch-diameter, alloy steel, with four-wing detachable tungsten carbide insert bits having a starting gage of 1-1/8-inch, is used. Bits are resharpened by shop personnel, and the gage is reduced 1/16 inch each time. Penetration rate is .25 inches per minute. All holes are loaded to the collar with 40-percent gelatin 1-1/8 by 16 inches and detonated with electric caps in the sequence shown in figure 18. Powder consumption was 21.3 pounds per linear foot.

An air-operated rocker shovel, with a capacity of 7.5 to 10.0 cubic feet, loads 2.5-ton, side-dump cars. The train of eight cars is trammed to the station by a 5-ton battery locomotive operated by the drift crew. Cars are switched by a Canton car transfer approximately 200 feet from the face. A mucking rate of 60 cubic feet per man-hour, including switching and tramming of 1,500 feet to the disposal area, is maintained in the drift. Track, consisting of 40-pound rail with a 24-inch gage, is laid subgrade by the drift crew and is brought to grade by the track crew.

The 10- by 11-foot drift was advanced 1.68 feet per man-shift by three crews of three men on a three-shift basis. The company furnished all equipment and supplies and delivered items to the shaft station.

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Polaris Mine

The Polaris mine, owned by the Polaris Mining Co., is in the Silver Belt area 1 mile west of Osburn, Idaho. Mine workings are accessible through a vertical shaft to the 3055 level. Collar of the shaft is about 6,000 feet from the portal of the main adit.

Ore deposits are found in St. Regis quartzite. Veins consist of tetrahedrite, pyrite, galena, and other minor sulfides. Dominant gangue materials are quartz and siderite. The veins generally strike N. 70° to 80° W. and dip southerly 55° to 75°. Mining method employed is modified square-set stoping, with waste fill where required by the ground conditions.

Driving methods were observed in an exploration crosscut 7.5 feet wide by 8.0 feet wide being advanced normal to the strike of quartzite beds, which at this point dip 70° N. and vary in thickness from 4 to 6 inches.

A V-cut round is drilled with two 3-1/2-inch automatic feed drifters mounted on a jumbo, and consists of 33 holes drilled to a depth of 6 feet. Round, 1-1/8-inch alloy steel, with four-wing 1-1/2-inch detachable tungsten carbide insert bits, is used. Bits are reground by shop personnel. Penetration rate is 28.7 inches per minute. All holes are loaded to the collar with a low-density nitrostarch after priming with one stick of 45-percent blasting gelatin and standard cap with safety fuse. Firing sequence is shown in figure 19. Powder consumed per linear foot of advance is 18.6 pounds.

An air-operated, rocker-type shovel having a capacity of 7.5 to 10.0 cubic feet, mucks into 2.5-ton, side-dump cars. Fourteen cars, enough to handle the entire round, and a 5-ton battery locomotive serve the heading. A mucking rate (which includes switching and tramming to the station when the shift ends) of 60 cubic feet per man-hour is attained. Switching is done with a Canton transfer placed 600 feet from the face. Tramming distance from the face to the disposal area at the station is about 2 miles. Track gage and weight are 18 inches and 30 pounds per yard. The heading requires no artificial support.

The face crew consists of two men working under contract, which is usually a verbal agreement between the crewmen and mine superintendent. Contract price was $13 per foot with equipment and supplies furnished by the company at the shaft station. The heading was advanced an average of 2.48 feet per man-shift.

Representative costs charged against the heading are $0.806 hoisting charge per ton of material handled, $1.196 per ton for haulage on the main adit, and $0.0187 for compressed air per foot of hole drilled.

Star Mine

The Star mine, operated by the Hecla Mining Co. for The Bunker Hill Co., is near Burke, 6 miles northeast of Wallace, Idaho. Underground operations are serviced by an 8,600-foot adit on the 2000 level to the main shaft,

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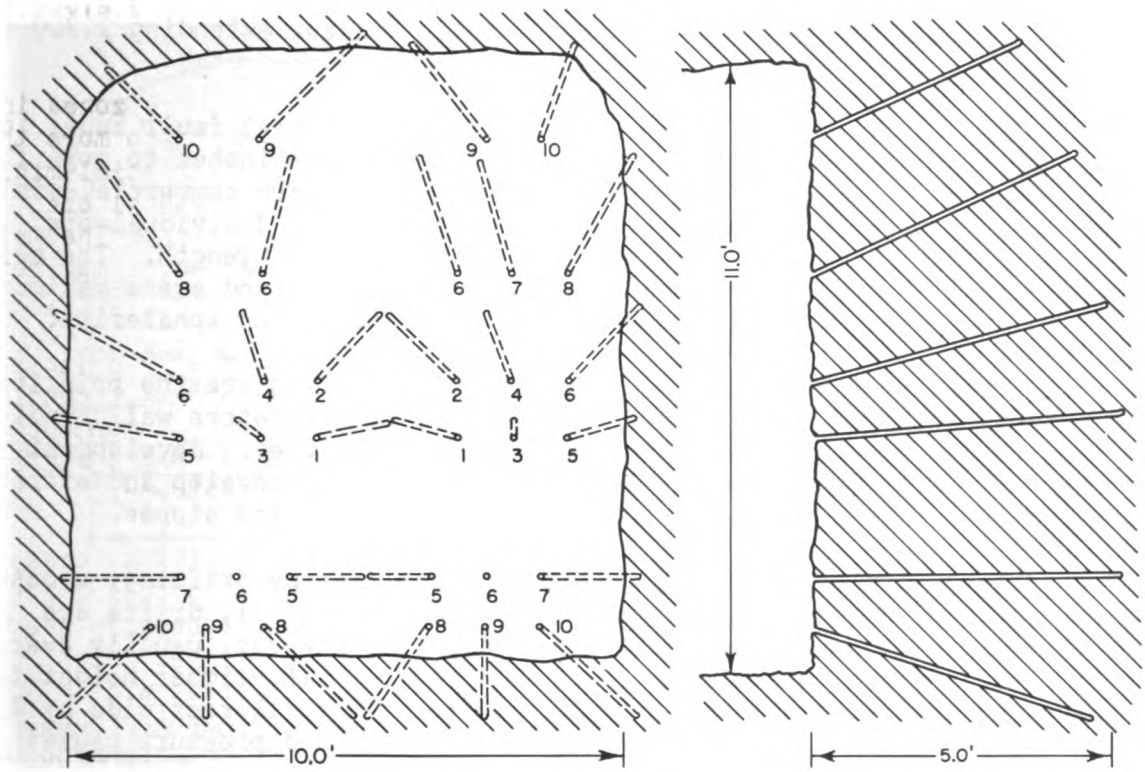

FIGURE 18. - Drift Round, 3070 Level (Page Mine).

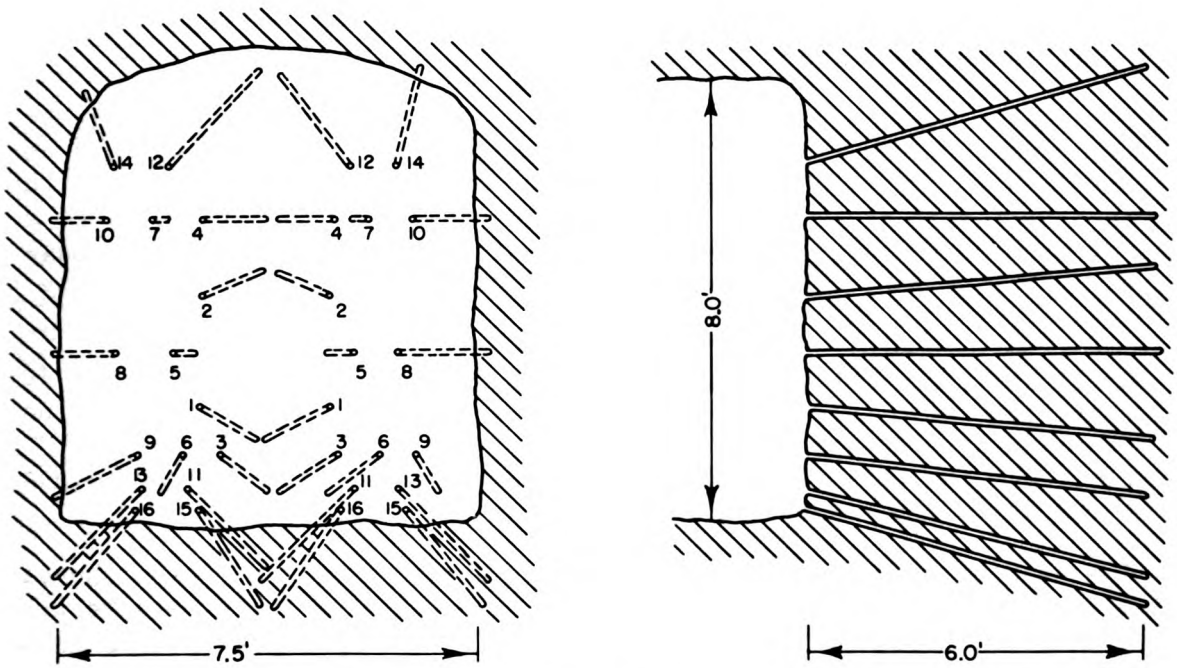

FIGURE 19. - Crosscut Round, 3000 Level (Polaris Mine).

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extending 2,000 feet below the adit level to the 4000 level. Access to workings below the 4000 level is by an offset vertical winze, extending 2,300 feet to the 6300 level at 539 feet below sea level.

Ore bodies in the Star mine are associated with several fault zones in Revett quartzite. The width of the ore varies from a few inches to more than 30 feet. Average commercial-vein width is 7 feet. Minimum commercial-mining width is about 4 feet in untimbered cut and fill stopes. Individual ore shoots are irregular in shape but show greater height than length. The main Star-Morning ore shoots extend some 6,600 feet vertically and are a maximum of 4,000 feet in length. Principal ore minerals are galena and sphalerite.

Horizontal-slice, stull-set, and cut-and-fill stoping are the principal mining methods employed. Untimbered cut and fill is used where wall conditions permit. In rare instances, shrinkage stoping is used. Development raises are driven at approximately 100-foot intervals to develop and extract the ore and to maintain an economic slushing distance in the stopes.

Prospecting, exploration, and development are done by drifting, crosscutting, raising, and underground diamond drilling. In general, drifts are driven the full width of the ore. A timbered drift, however, usually averages 10 to 11 feet in width to allow room for equipment. Drift-timber height is 10 feet above the rail, making the rock cross section 10 to 11 feet wide by 11 to 12 feet high. In the lower levels where excessive ground pressure causes high maintenance and repair costs, drifts are driven in the hanging wall about 40 feet from the ore zone.

Driving methods were observed in one heading--a development drift in the vein driven 13 feet high and approximately 15 feet wide in an area where the vein is nearly vertical. The country rock is massive thick-bedded Revett quartzite, generally solid, although sheared and broken in some areas.

A three-hole burn cut with relievers and a modified V-cut round is drilled with twin 3-inch automatic feed drifters mounted on a jumbo. The round consists of 45 holes drilled to a depth of 5.4 feet. Four-wing detachable tungsten carbide insert bits with a starting gage of 1-5/8 inch, resharpened and gaged by shop personnel, are used on hexagonal, 1-inch carbon steel. Gage is reduced 1/16 inch for each change in length of steel. A penetration rate of 31 inches per minute is attained.

Drill holes are bottom-primed with one stick of 45-percent gelatin dynamite sensitized with safety fuse and standard cap. The holes are then loaded to the collar with low-density nitrostarch explosive. One hole is left unloaded. A total of 19.3 pounds of powder is consumed per foot of advance. Detonation is in the sequence shown in figure 20.

The heading is mechanically mucked with an air-operated rocker shovel having a capacity of 7.5 to 10.0 cubic feet. Because of the excessive width of the drift, it is necessary to hand-shovel, slush, or install short rails at an angle to the main line to muck the sides of the heading. The mucking rate, including switching and tramming a maximum of 1,200 feet to the station, is

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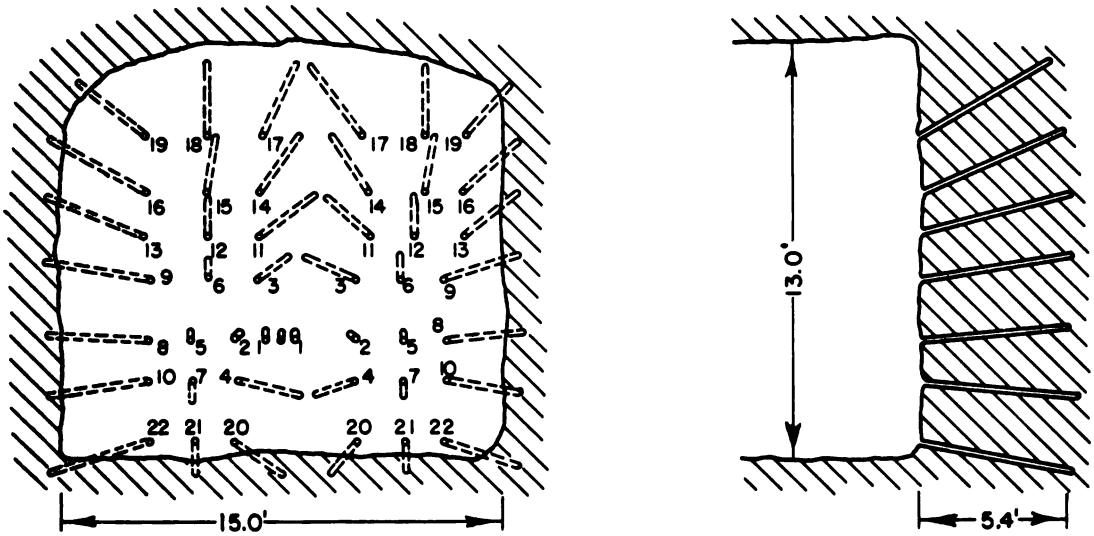

• Holes not loaded.

FIGURE 20. - Drift Round, 5900 Level (Star Mine).

100 cubic feet per man-hour. Four 50-cubic-foot-capacity rocker-dump cars and a 5-ton battery locomotive serve the drift. Initial switching was at a junction 200 feet from the face; later, a Canton car transfer was installed for distances over 300 feet from the switch point. Track gage and weight is 24 inches and 30 pounds per yard.

Timber is required in all drifts, and regular drift sets are installed on 5-foot centers. Because of the drift width, installation is accomplished in an unusual manner. A cap, 14 to 18 inches in diameter and about 4 feet shorter than drift width to allow for blocking, is pulled atop the muck pile by the motor and is raised to a position level with the cap of the set next to it. The cap is then wedged as tight as possible, and each end is blocked with 24 inches of 3-inch headboards. Side pressure is sufficient to support the cap and back lagging during the mucking cycle. Posts are installed after the broken round is removed. Girts, 3 by 6 inches by a length sufficient to fit between the posts, are nailed to the posts beneath the caps. Girts are also placed between the caps. Back blocking or cribbing is completed before another round is blasted. Approximately 9.5 man-hours are needed to install a set.

The face crew consists of three men working the heading under contract. Supplies and equipment are furnished by the company at the shaft station. The heading is advanced at a rate of 1.12 feet per man-shift on a basis of three shifts a day.

Sunshine Mine

The Sunshine mine is in the Silver Belt district, 3 miles southeast of Kellogg, Idaho. Underground operations are serviced by the Jewell shaft, which extends to the 3840 level. Access to mine workings can also be made

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through other shafts or vertical winzes. Ore bodies occur in shear zones, and the most productive is in the St. Regis formation. The veins of the mine strike approximately east and west and dip 70° to 80° S. Ore minerals include silver-bearing tetrahedrite, galena, chalcopyrite, and sphalerite.

Several mining methods are employed. Narrow stopes are supported by stulls and headboards, but the wider stopes are mined by conventional square-set stoping. Levels are 150 feet apart, and stopes are mined from level to level and waste-filled. Stopes are usually 8 to 20 feet wide.

Driving methods were observed in three headings, two exploration drifts, and a crosscut. The drifts are about 7 feet wide by 8 feet high and are being driven in the ore zone on the 3700 level and 4000 level. The crosscut, about 8.0 feet wide by 8.5 feet high, is being advanced normal to the strike of hard quartzite beds, which are 4 to 6 inches thick and dip about 70° N.

In the 3700 drift, a V-cut of 36 holes is drilled to a depth of 92 inches. In the 4000 drift, a V-cut of 47 holes is drilled to a depth of 90 inches. A pyramid cut of 39 holes drilled to a depth of 84 inches was used in the 3850 crosscut. All rounds are drilled with two 2-3/4-inch automatic feed drifters mounted on a jumbo. Hexagonal, 7/8-inch alloy steel, with four-wing, 1-3/8-inch detachable tungsten carbide insert bits, is used in all headings. Bits are resharpened and gaged by shop personnel. A complete and accurate record of bit consumption for each heading is kept by the shift bosses. Approximately 166 feet was drilled per bit in the 3700 drift, 245 feet per bit in the 4000 drift, and 385 feet per bit in the 3850 crosscut. Penetration rates were 25.8 inches per minute in the 3700 drift, 23.0 inches per minute in the 4000 drift, and 18.0 inches per minute in the 3850 crosscut. All holes are loaded to the collar with 50-percent straight dynamite and detonated by standard caps, using 10-foot safety fuse in the sequence shown in figures 21, 22, and 23. Powder consumption is 15.0 pounds per linear foot in the 3700 drift, 23.1 pounds per foot in the 4000 drift, and 25.7 pounds per foot in the crosscut, which was reported to bootleg considerably.

In the 3700 drift, an air-operated rocker shovel having a capacity of 4.5 to 6.0 cubic feet mucks into 2.5-ton cars. A 5-ton battery-operated locomotive services the headings. A mucking rate of 58 cubic feet per man-hour is attained in the drift. Cars are switched at a junction 125 feet from the face. An overhead car transfer is installed when the switching distance is greater than 250 feet.

Timber is not used in any of the headings. Rock bolts, where necessary, are inserted in the drifts and crosscuts. A fanlike pattern of 4-foot, expansion shell-type bolts is used on 4-foot centers.

All exploration and development work is done under contract. The contract price varies in each heading and depends upon the type of ground, size of heading, etc. The 3700 drift is advanced by a two-man crew working the third shift. The 4000 drift and 3850 crosscut are being driven on two shifts with one man per shift. Drilling, loading, and blasting are done on one shift; mucking, installation of track, pipe, and ventilation lines are accomplished

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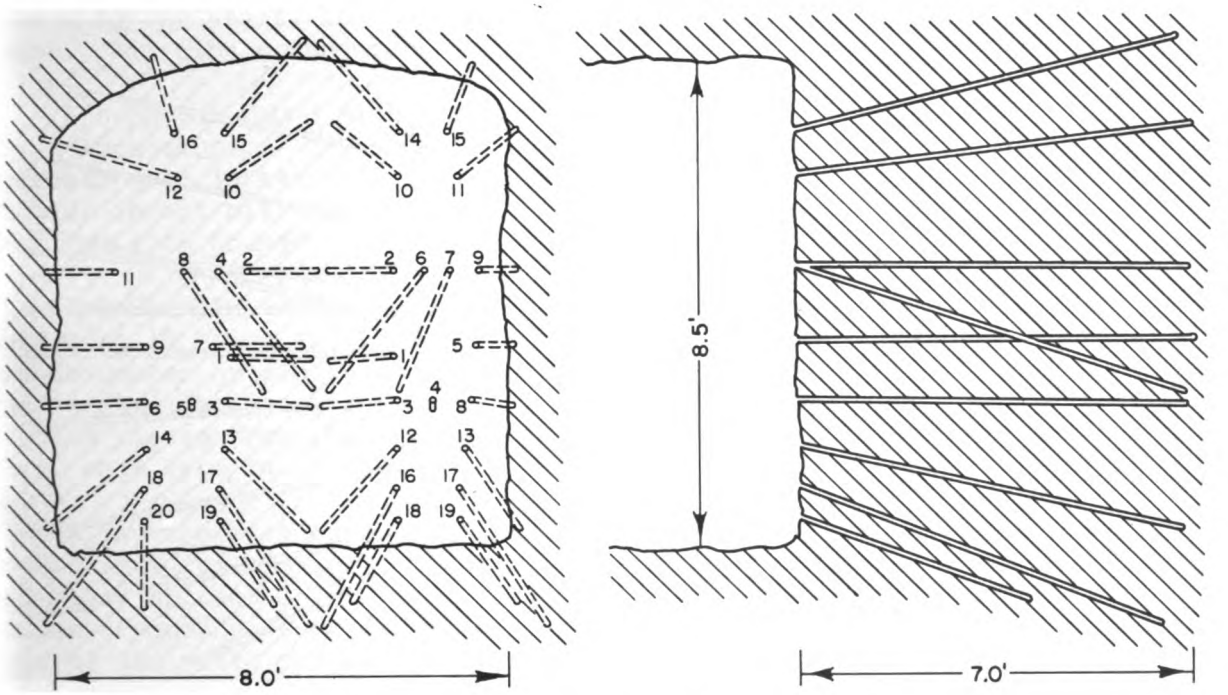

FIGURE 21. - Crosscut Round, 3850 Level (Sunshine Mine).

on the other shift. A motorman assists the miners during the mucking cycle in the 4000 drift and 3850 crosscut. All supplies and equipment are furnished by the company at the shaft station.

All contracts are awarded through a bidding system; therefore, it is possible that inexperienced miners may attempt to advance a heading. This happened in the 3850 crosscut. The advance of 2.64 feet per man-shift in this heading does not indicate the average of the mine. The 3700 and 4000 drifts were advanced by experienced miners at a rate of 3.35 and 3.56 feet per man-shift, respectively.

RAISING

Bunker Hill Mine

Raising methods were observed in a 5.0- by 5.5-foot untimbered raise, inclined 45°, that penetrated thin-bedded quartzite of the Revett formation, which dips steeply to the south.

The raise is ventilated through sublevel openings from the No. 3 shaft. The openings are on 400-foot vertical intervals, and there is enough fresh air to remove gases from the face and to supply fresh air to the men working in the raise. Water and compressed air are supplied from the No. 3 shaft by 2-inch pipelines through the sublevel opening nearest the face. A 3/4-inch water hose and a 1-inch air hose supply water and air to the stopes from the 1-inch water pipe and the 2-inch air pipe in the raise. Control valves are

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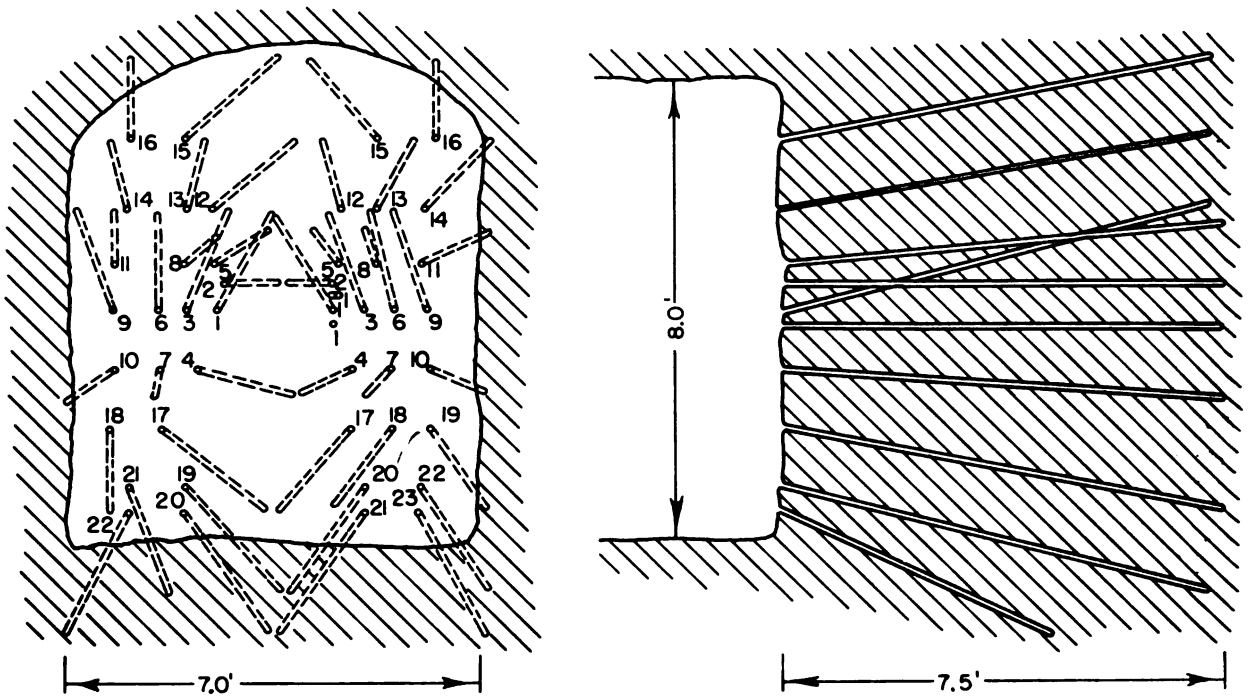

FIGURE 22. - Drift Round, 4000 Level (Sunshine Mine).

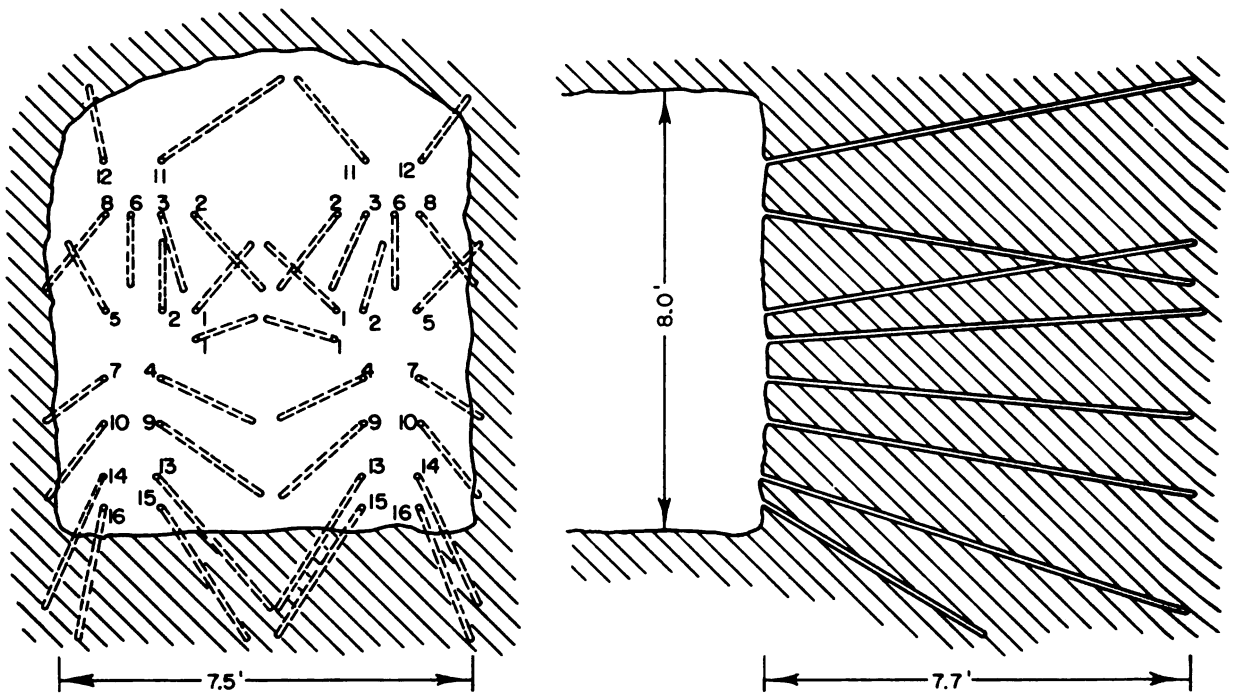

FIGURE 23. - Drift Round, 3700 Level (Sunshine Mine).

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placed in the shaft, in the sublevel, and at the outlet from the pipe to the hoses. All pipe connections are made with victaulic couplings.

A burn-cut round with 22 holes is drilled to a depth of 7.5 feet with a 2-3/4-inch stoper. Hexagonal, 7/8-inch alloy steel with an 18-inch length, increasing 18 inches for each change, is used with 4-wing detachable tungsten carbide insert bits having a starting gage of 1-5/8 inches and decreasing 1/16 inch for each change.

The 22-hole round includes 4 full-length unloaded relief holes. The remaining 18 holes are loaded to the collar with 45 percent-blasting gelatin and detonated by electric caps. Firing sequence of the round is shown in figure 24. The face is drilled from a stage consisting of a piece of 3-inch lagging placed from the footwall of the raise across an adjustable steel support, made from two 4-foot drill rods held together by U-bolt clamps.

A two-man face crew advances the heading one shift per day. An advance of 3.5 feet per man-shift is made by completing a cycle of drilling, loading, and blasting each day. The raise is being driven under a contract, and the company furnishes supplies and equipment at the sublevel opening nearest the face of the waste pass. Price per foot of advance was $10.90.

Lucky Friday Mine

Raising methods were observed in a four-compartment raise driven in an ore zone consisting of galena and tetrahedrite, with quartz and siderite the dominant gangue minerals. Country rock is quartzite of the St. Regis formation.

Vertical raise 111, 5 by 19 feet, is drilled with two 2-3/4-inch stopers. Hexagonal, 7/8-inch alloy steel with 30-inch length, increasing 18 inches for each change, is used with 4-wing detachable tungsten carbide insert bits having a starting gage of 1-5/8 inches and decreasing 1/16 inch for each change. A V-cut round of 53 holes is drilled to a depth of 5.8 feet at a penetration rate of 32 inches per minute.

The 53-hole round is loaded to the collar with a low-density nitrostarch powder and detonated by standard caps with 12-foot safety fuse. Firing sequence of the round is shown in figure 25. A total of 15.8 pounds of powder is consumed per foot of advance.

The raise was timbered with a three-cap raise set consisting of six posts, three caps, eight girts, and the necessary lagging, blocks, and wedges. Timbering a complete floor in the raise required 13.4 man hours. A typical four-compartment raise is shown in figure 10. The outer compartments are untimbered, except for girts, and are used as chutes. Inner compartments are used as hoistway and manway. Air, water, and ventilation lines are installed in the manway, and are carried as close to the face as possible.

Compressed air and water are supplied to the stopers by 2-inch pipelines. A 1-inch air hose and a 1/2-inch water hose supply air and water to stopers

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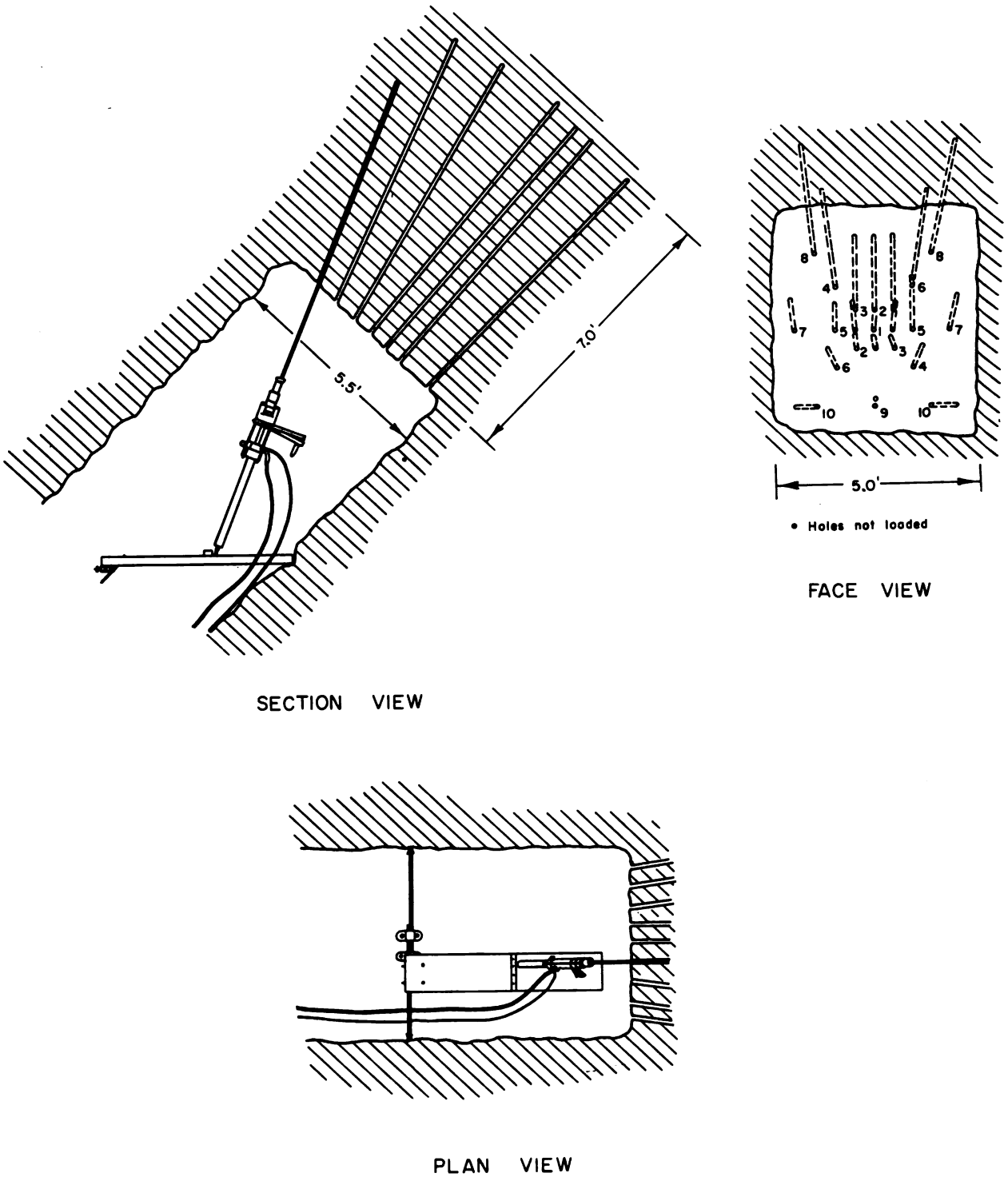

FIGURE 24. - Drill Round and Setup, No. 3 Waste Pass (Bunker Hill Mine).

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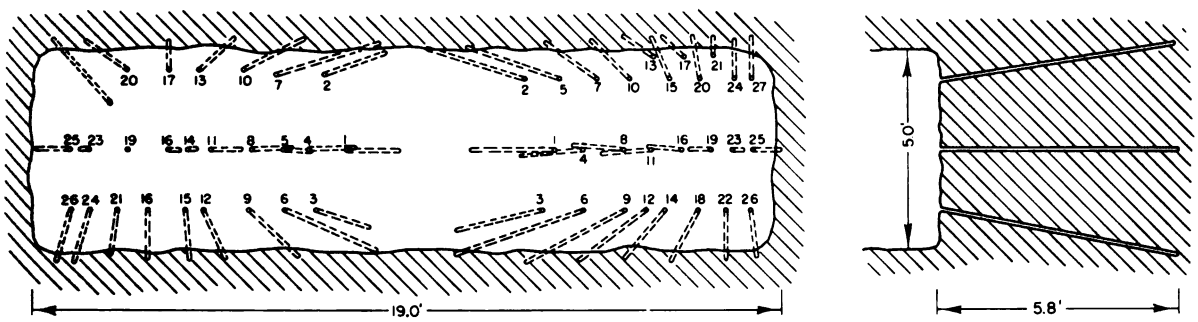

FIGURE 25. - Raise Round (Lucky Friday Mine).

from the pipelines. Valves for both lines are placed at the bottom of the raise and at outlets from the pipe to the hose. All pipe connections are made with victaulic couplings.

The three-man face crew advanced the heading one shift per day at an average rate of 0.82 feet per man-shift. Drilling, loading, and blasting alternated with timbering and other duties from day to day. The raise is driven at a contract price of $34 per foot, which includes breaking, timbering, tramming of broken rock to the shaft station, and all other labor necessary to advance the raise. All equipment and supplies are furnished at the shaft station by the company.

Polaris Mine

Raising operations were observed in a four-compartment raise driven in an ore zone. Mineralization encountered during raising consisted of minor amounts of sulfide minerals, with quartz and siderite the dominant gangue minerals. Country rock is quartzite of the St. Regis formation.

A V-cut round of 56 holes is drilled to a depth of 6.5 feet with two 3-1/8-inch stopers. Five changes of quarter-octagon, 7/8-inch alloy steel, with an increase of 18 inches in length for each change, are used with four-wing detachable tungsten carbide insert bits, starting at 1-5/8 inches and decreasing 1/16 inch for each change. A penetration of 27.3 inches per minute is made.

The round is loaded to the collar with a low-density nitrostarch explosive and detonated by standard caps with 12-foot safety fuse in the sequence shown in figure 26. Powder consumption was 22.5 pounds per linear foot.

Timbering a complete floor in the raise requires 12.3 man-hours, of which approximately 6 percent is consumed cleaning off the bulkhead.

Air, water, and ventilation lines are carried to within 25 feet of the face. Compressed air and water is supplied to the raise by 2-inch pipelines from the main lines. A 1-1/4-inch air hose and a 1-inch water hose supply air

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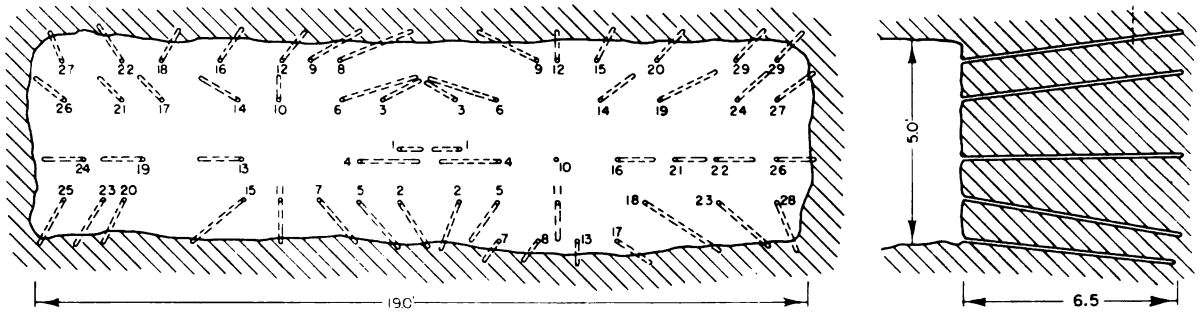

FIGURE 26. - Raise Round (Polaris Mine).

and water to the stopers from the pipelines. Valves are placed at the outlets from the main lines to the 2-inch pipelines, and at the outlet from the pipelines to the hoses. A small blower-type fan installed about 6 feet above the sill forces air through a collapsible fan bag to the face.

The raise is advanced by a three-man crew working one shift per day. An advance of 0.82 feet per man-shift is made by drilling, loading, and blasting on one day and performing timbering and other duties the next day. The contract under which the raise is driven is usually a verbal agreement between the contractors and the mine superintendent. It specifies the amount to be paid per foot of advance as well as the quality and quantity of work. Supplies and equipment are furnished by the company. The contract price is $35 per foot.

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TABLE 4. - General information

Mine heading	Bunker		Crescent		Hercules	Lucky Friday		Page	Polaris	Star	Sunshine		
	18D	26XC	3100D	2500D	1900D	2600D	3050XC	3070D	337XC	5900D	3850XC	4000D	3700D
Rock section.....ft.	10x12	9x9	9x9	9x9	8x8.5	7.5x8	8.5x9	10x11	7.5x8	12x12	8x8.5	7x8	7.5x8
Total adv.....ft.	281.5	423.5	616.0	372.0	90.5	253.9	113.6	10.0	559.1	569.8	79.0	134.0	101.0
Contract shifts.....	96	132	160	92	40	76	38	6	240	513	30	40	30
Timber.....	Drift sets	None	None	None	None	None	None	Drift sets	None	Drift sets	None	None	None
Drilling:													
Machine.....	Drifter	Drifter	Drifter	Drifter	Drifter	Air leg	Air leg	Drifter	Drifter	Drifter	Drifter	Drifter	Drifter
Size.....	3"	3"	3"	3"	3-1/2"	2-1/2"	2-1/2"	3-1/2"	3-1/2"	3"	2-5/8"	2-5/8"	2-5/8"
Mount.....	Jumbo	Jumbo	Jumbo	Jumbo	Jumbo	Air leg	Air leg	Jumbo	Jumbo	Jumbo	Jumbo	Jumbo	Jumbo
Penetration....in./min. 1/	21.5	16.0	18.0	15.0	18.9	19.0	22.1	25.0	28.7	31.0	18.0	23.0	25.8
Steel:													
Size.....	1-1/8"	1-1/8"	1-1/8"	1-1/8"	1"	7/8"	7/8"	1-1/8"	1-1/8"	1"	7/8"	7/8"	7/8"
Shape.....	Round	Round	Round	Round	Round	Hex.	Hex.	Round	Round	Hex.	Hex.	Hex.	Hex.
Type.....	Alloy	Alloy	Alloy	Alloy	Carbon	Alloy	Alloy	Alloy	Alloy	Carbon	Alloy	Alloy	Alloy
Bits:													
Size.....	1-5/8"	1-3/8"	1-3/8"	1-3/8"	1-5/8"	1-9/16"	1-9/16"	1-5/8"	1-1/2"	1-5/8"	1-3/8"	1-3/8"	1-3/8"
Type 2/.....	Steel bits	D.T.C.	D.T.C.	D.T.C.	D.T.C.	I.T.C.	I.T.C.	D.T.C.	D.T.C.	D.T.C.	D.T.C.	D.T.C.	D.T.C.
Round:													
Type.....	V-cut	V-cut	V-cut	V-cut	V-cut	Burn	Burn	V-cut	V-cut	(3)	Pyramid	V-cut	V-cut
Number of holes.....	26	38	38-39	43	54	33	33	33	33	45	39	47	36
Depth.....ft.	6.0	7.5	8.0	8.0	6.5	6.5	6.5	5.0	6.0	5.4	7.0	7.5	7.7
Figure.....	11	12	13	14	15	16	17	18	19	20	21	22	23
Explosive: Type.....	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Nitro-starch	Nitro-starch	Dynamite	Dynamite	Dynamite
Strength.....	45%	45%	60%	60%	45%	40%	40%	40%	Low density	Low density	50%	50%	50%
Lbs./ft.....	14.6	21.9	23.8	24.8	33.5	15.3	14.9	21.3	18.6	19.3	25.7	23.1	15.0
Cu.ft.rock/lb.....	8.2	3.7	3.4	3.3	2.3	3.9	5.1	5.2	3.2	7.5	2.6	2.4	3.5
Primer:													
Type.....	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Gelatin	Dynamite	Dynamite	Dynamite
Strength.....	45%	45%	60%	60%	60%	40%	40%	40%	45%	45%	50%	50%	50%
Detonator:													
Type.....	Electric	Electric	Electric	Electric	Fuse	Electric	Electric	Electric	Fuse	Fuse	Fuse	Fuse	Fuse
Delay.....	Regular	Regular	Regular and M.S.	Regular and M.S.	Standard	Regular	Regular	Regular	Standard	Standard	Standard	Standard	Standard
Mucker: Type.....	Overshot	Overshot	Overshot	20 hp. slusher	Overshot	Overshot	Overshot	Overshot	Overshot	Overshot	Overshot	Overshot	Overshot
Capacity.....cu. ft.	7.5-10.0	7.5-10.0	7.5-10.0	10.0	7.5-10.0	4.5-6.0	4.5-6.0	7.5-10.0	7.5-10.0	7.5-10.0	4.5-6.0	4.5-6.0	4.5-6.0

1/ Measured.
2/ D.T.C., four-wing detachable tungsten carbide insert and I.T.C., integral tungsten carbide chisel bit.
3/ V-with burn.

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TABLE 5. - Labor distribution 1/

Mine heading	Bunker		Crescent		Hercules	Lucky Friday		Page	Polaris	Star 2/	Sunshine		
	18D	26XC	3100D	2500D	1900D	2600D	3050XC	3070D	337XC	5900D	3850XC	4000D	3700D
Performance													
Setup.....man-hours/ft.	0.08	0.06	0.07	0.15	0.18	0.15	0.17	0.20	0.07	0.62	0.06	0.05	0.19
Drilling.....do..	.36	.63	.42	.53	1.20	.59	.75	.59	.71	1.44	.56	.50	.52
Load and blast.....do..	.18	.23	.13	.16	..21	.30	.25	.45	.31	.54	.24	.23	.22
Mucking.....do..	.57	.48	.52	.66	.98	.77	.65	1.83	1.00	2.19	3/1.26	3/ .87	.90
Timbering.....do..	.33	-	-	-	-	-	-	.83	-	1.89	-	-	-
Track and ventilation..do..	-	-	.28	.04	.33	.17	.12	.25	.23	.32	-	-	-
Miscellaneous.....	1.17	1.10	.66	.46	.66	.54	.74	.65	.90	.20	.91	.60	.56
Total.....man-hours/ft.	2.69	2.50	2.08	2.00	3.56	2.52	2.68	4.80	3.22	7.20	3.03	2.25	2.39
Summary 4/													
Advance:													
Ft./man-hour.....	.37	.40	.48	.50	.28	.40	.37	.21	.31	.14	.33	.44	.42
Ft./man-shift.....	2.96	3.23	3.85	4.00	2.25	3.17	2.98	1.68	2.48	1.12	2.64	3.56	3.35
Cu. ft./man-hour.....	44.4	32.4	38.9	40.5	21.4	23.4	28.3	23.1	18.6	20.0	22.4	24.6	25.2
Mucking:													
Cu. ft./man-hour.....	210.0	165.0	155.0	122.0	78.0	78.0	115.0	60.0	60.0	100.0	54.0	64.0	67.0

1/ Obtained by time studies except footnote 2.
2/ Information obtained from time distribution records.
3/ Includes installation of track and conduits.
4/ For total advance of headings.

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TABLE 6. - Summary of costs 1/

Mine heading	Bunker		Crescent		Hercules	Lucky Friday 2/		Polaris	Star	Sunshine		
	18D	26XC	3100D	2500D	1900D	2600D	3050XC	337XC	5900D	3850XC	4000D	3700D
Labor:												
Setup	1.3	0.9	1.2	2.9	2.8	2.5	2.8	1.2	4.2	1.1	1.3	4.4
Drilling	6.1	9.6	7.1	10.0	18.7	9.7	12.4	12.6	9.8	9.7	12.9	12.0
Load and blast	3.0	3.5	2.2	3.1	3.3	4.9	4.2	5.5	5.0	4.2	5.9	5.1
Mucking	9.6	7.3	8.9	12.6	15.3	12.8	10.8	17.8	14.9	21.9	22.4	20.9
Timbering	5.5	-	-	-	-	-	-	-	13.8	-	-	-
Track and ventilation	-	-	5.0	.8	5.1	2.8	2.0	4.1	2.1	-	-	-
Nonwage	6.1	5.0	4.8	5.0	-	5.1	5.6	-	-	7.9	8.7	8.3
Miscellaneous	19.7	16.8	11.0	8.8	10.3	9.0	12.3	16.0	1.4	15.8	15.4	13.0
Total	51.3	43.1	40.2	43.2	55.5	46.8	50.1	57.2	51.2	60.6	66.6	63.7
Supervision and Engineering	3.3	10.2	6.7	6.9	-	-	-	3.6	3.1	-	-	-
Materials:												
Track	-	-	-	-	7.8	-	-	1.2	4.3	-	-	-
Powder and primers	13.2	10.1	-	-	27.4	-	-	18.0	9.2	-	-	-
Bits and rods	3.9	9.6	-	-	-	-	-	13.5	7.4	-	-	-
Timber and rock bolts	19.3	7.1	-	-	-	-	-	-	15.8	-	-	-
Pipe	.5	2.5	-	-	8.1	-	-	.1	4.1	-	-	-
Ventilation supplies	.2	-	-	-	1.2	-	-	-	1.2	-	-	-
Total	37.1	29.3	35.8	36.8	44.5	47.0	45.4	32.8	42.0	39.4	33.4	36.3
Repair	2.9	9.4	12.2	7.6	-	6.2	4.5	6.4	1.7	-	-	-
Miscellaneous	5.4	8.0	5.1	5.5	-	-	-	-	2.0	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Apportionment of costs, percent		Apportionment of average actual costs per foot		Apportionment of average costs per cubic foot	
Labor, supervision and engineering	55.3	Labor, supervision and engineering	$23.32	Labor, supervision and engineering	$0.279
Materials and repair	42.5	Materials and supplies	17.92	Materials and supplies	.215
Miscellaneous	2.2	Miscellaneous	.93	Miscellaneous	.012
Total	100.0	Total	42.17	Total	.506

1/ In percent of total costs.
2/ Estimated.

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TABLE 7. - General information

	Bunker	Lucky Friday	Polaris
Raise.....	3	111	68
Inclination.....	45°	Vertical	Vertical
Rock section.....feet	5 x 5.5	5 x 19	5 x 19
Total advance.....do..	407.5	150	59.4
Total man-shifts.....	118	183	60
Timbering.....	No	Yes	Yes
Drilling:			
Machine.....	Stoper	Stoper	Stoper
Size.....inch	2-3/4	2-3/4	3-1/8
Penetration...in./min.	14.0	32.0	27.3
Steel:			
Size.....inch	7/8 hexagonal	7/8 hexagonal	7/8 hexagonal
Type.....	Alloy	Alloy	Alloy
Change.....do..	18	18	18
Bits:			
Type 1/.....	D.T.C.	D.T.C.	D.T.C.
Size.....do..	1-5/8	1-5/8	1-5/8
Explosives:			
Type.....	Gelatin	Nitrostarch	Nitrostarch
Strength.....	45%	Low density	Low density
Detonator.....	Electric delays	Cap and fuse	Cap and fuse
Lb./ft.....	12.3	15.8	22.5
Cu. ft. of rock/lb....	2.2	6.0	4.0
Round:			
Type.....	Burn	V-cut	V-cut
Number of holes.....	22	53	56
Depth.....feet	7.5	5.8	6.5
Figure.....	24	25	26

1/ D.T.C. Four-wing detachable tungsten carbide insert bits.

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TABLE 8. - Labor distribution

	Bunker	Lucky Friday	Polaris
Raise.....	3	111	68
Performance:			
Labor:			
Setup.....man-hour foot	0.26	0.26	0.27
Drilling.....do.....	1.23	2.03	1.76
Load and blast...do.....	.22	.81	.36
Bulkhead.....do.....	-	.61	.54
Timbering.....do.....	-	2.67	2.46
Mucking.....do.....	-	.61	.54
Miscellaneous....do.....	.61	2.74	2.69
Total.....	2.32	9.73	8.62
Summary 1/:			
Advance:			
Foot per man-hour.....	.43	.10	.12
Foot per man-shift.....	3.45	.82	.93
Cubic foot per man-hour..	11.8	9.5	11.4
Timbering:			
Foot per man-hour.....	-	.37	.41
Foot per man-shift.....	-	2.98	3.25
Man hours per set.....	-	13.4	12.3

1/ For total advance.

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TABLE 9. - Summary of costs 1/

	Bunker	Lucky Friday 2/	Polaris
Raise.....	3	111	68
Labor:			
Setup.....	4.1	1.1	1.9
Drilling.....	19.6	8.3	12.3
Load and blast.....	3.5	3.3	2.5
Bulkhead.....	-	2.4	3.8
Timbering.....	-	10.9	17.2
Mucking.....	-	2.4	3.7
Nonwage.....	5.2	5.1	-
Miscellaneous.....	9.7	11.2	18.8
Total.....	42.1	44.7	60.2
Materials.....	47.0	41.9	37.5
Repair.....	6.2	9.8	2.3
Miscellaneous.....	4.7	9.8	-
Total.....	100.0	100.0	100.0

Apportionment of total costs (percent)		Apportionment of actual costs per cubic foot (dollars)	
Labor.....	49.0	Labor.....	0.362
Materials and repair..	46.2	Materials and repair...	.342
Miscellaneous.....	4.8	Miscellaneous.....	.036
Total.....	100.0	Total.....	0.740

1/ In percent of total costs.
2/ Estimated.

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